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(12) **United States Patent**
Jacobsen et al.

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(45) **Date of Patent:** **Mar. 8, 2022**

(54) **SACRO-ILIAC (SI) JOINT FIXATION SYSTEM AND METHOD**

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(73) Assignee: **CTL Medical Corporation**, Addison, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/797,861**

(22) Filed: **Feb. 21, 2020**

(65) **Prior Publication Data**
US 2020/0268518 A1 Aug. 27, 2020

Related U.S. Application Data

(60) Provisional application No. 62/809,419, filed on Feb. 22, 2019.

(51) **Int. Cl.**
A61F 2/30 (2006.01)
A61F 2/44 (2006.01)

(52) **U.S. Cl.**
CPC **A61F 2/30988** (2013.01); **A61F 2/4455** (2013.01); **A61F 2002/3085** (2013.01); **A61F 2002/30405** (2013.01); **A61F 2002/30622** (2013.01); **A61F 2002/30736** (2013.01); **A61F 2002/30995** (2013.01)

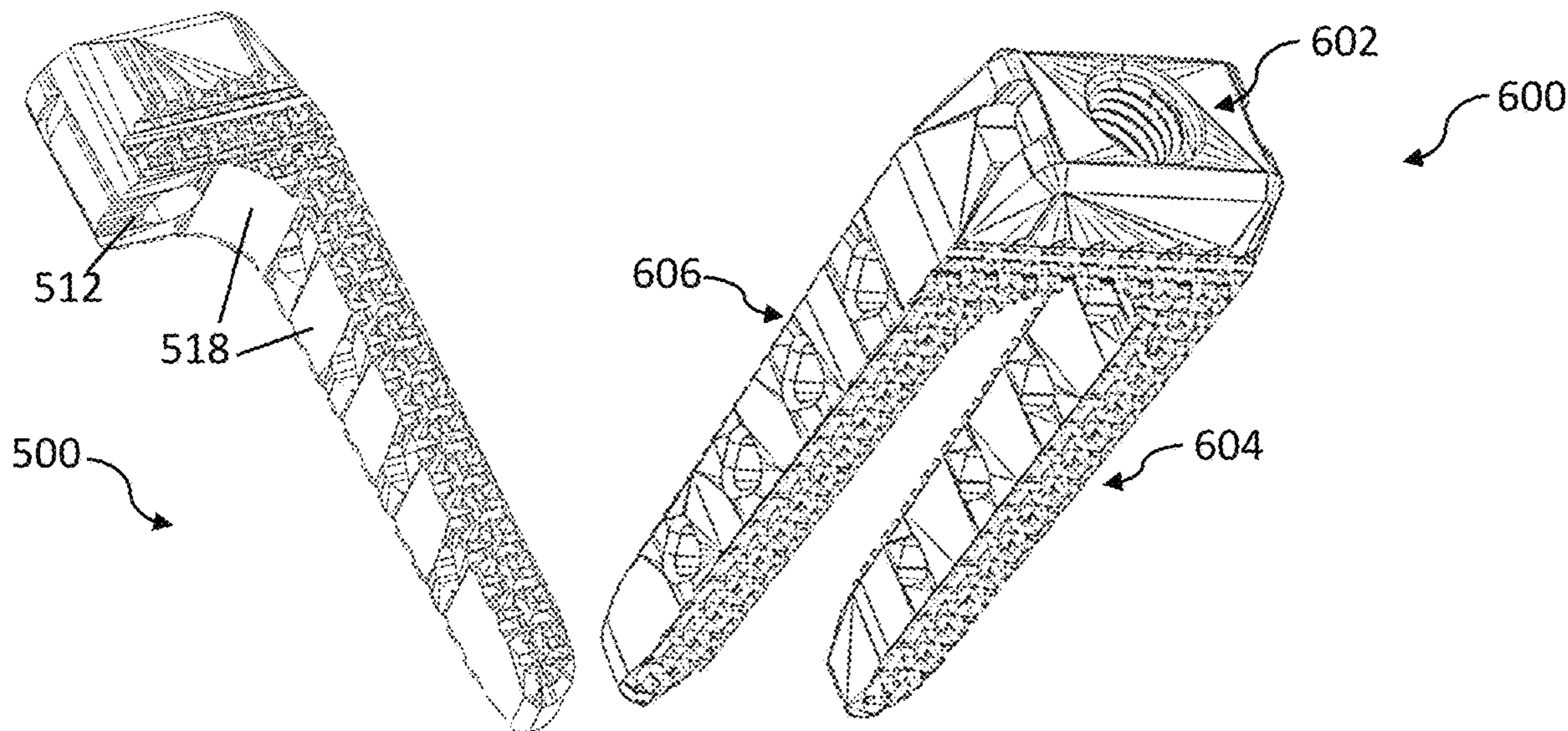
(58) **Field of Classification Search**
CPC **A61F 2/4455**; **A61F 2002/30995**; **A61F 2/30988**
See application file for complete search history.

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Primary Examiner — Christian A Sevilla
(74) *Attorney, Agent, or Firm* — Brainspark Associates, LLC

(57) **ABSTRACT**
Disclosed is a sacro-iliac joint fusion system including a block or wedging cage positioned between the sacrum and iliac bone, wherein the block or wedging cage can fit around one or more fixation or axial screws to fasten the block or wedging cage and secure the block or wedging cage to the adjacent pelvic bones to promote fusion and fixation.

20 Claims, 41 Drawing Sheets



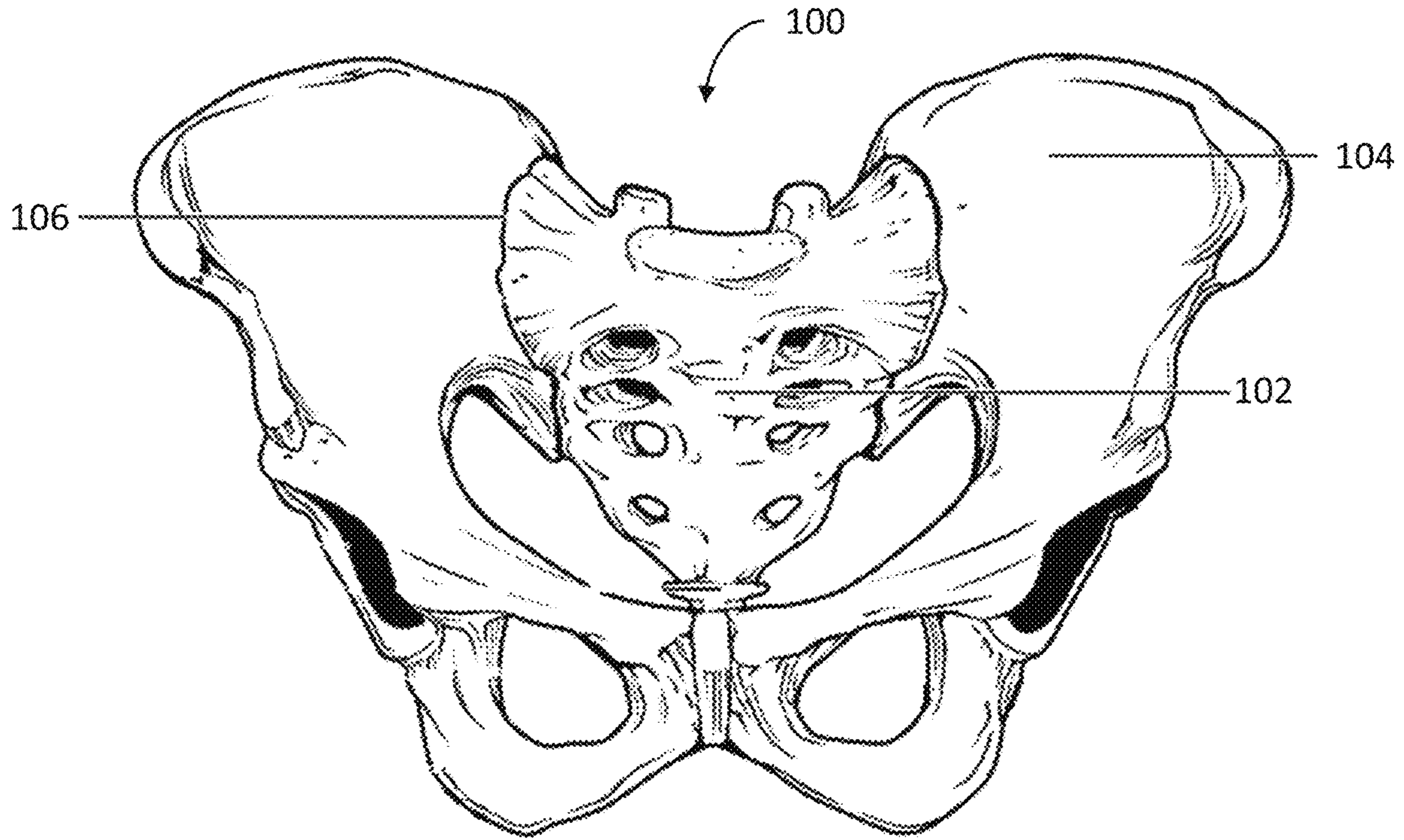


FIG. 1A

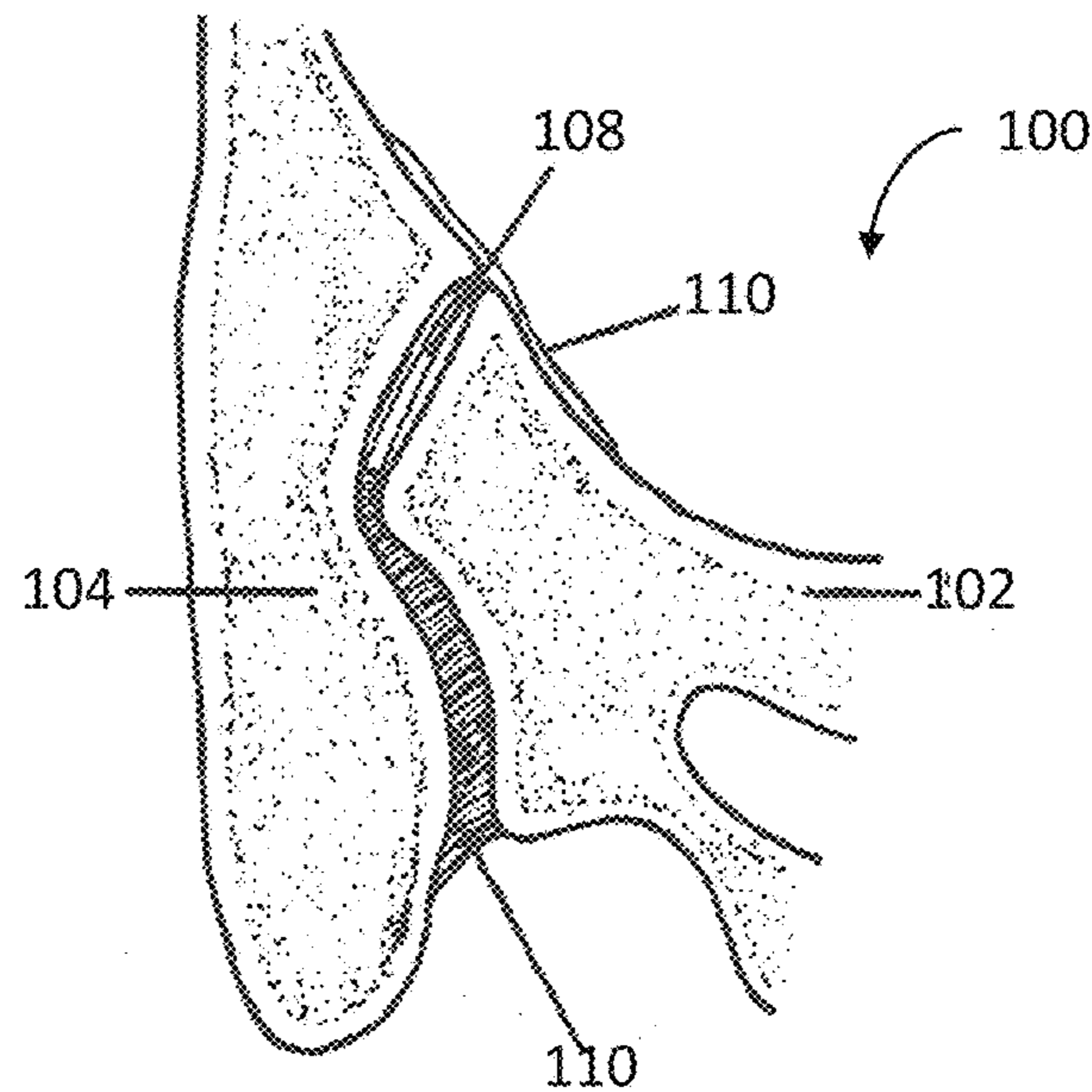
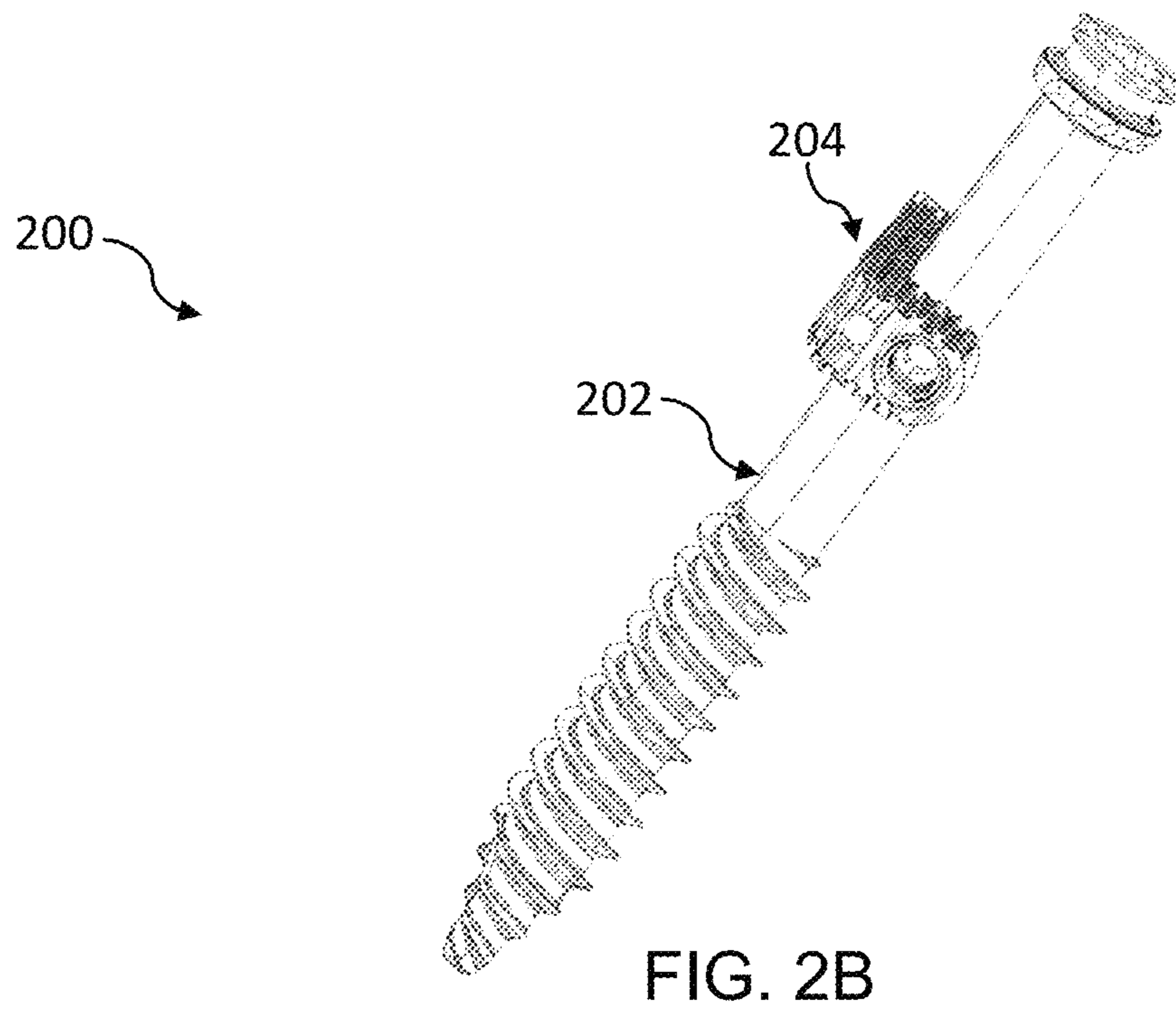
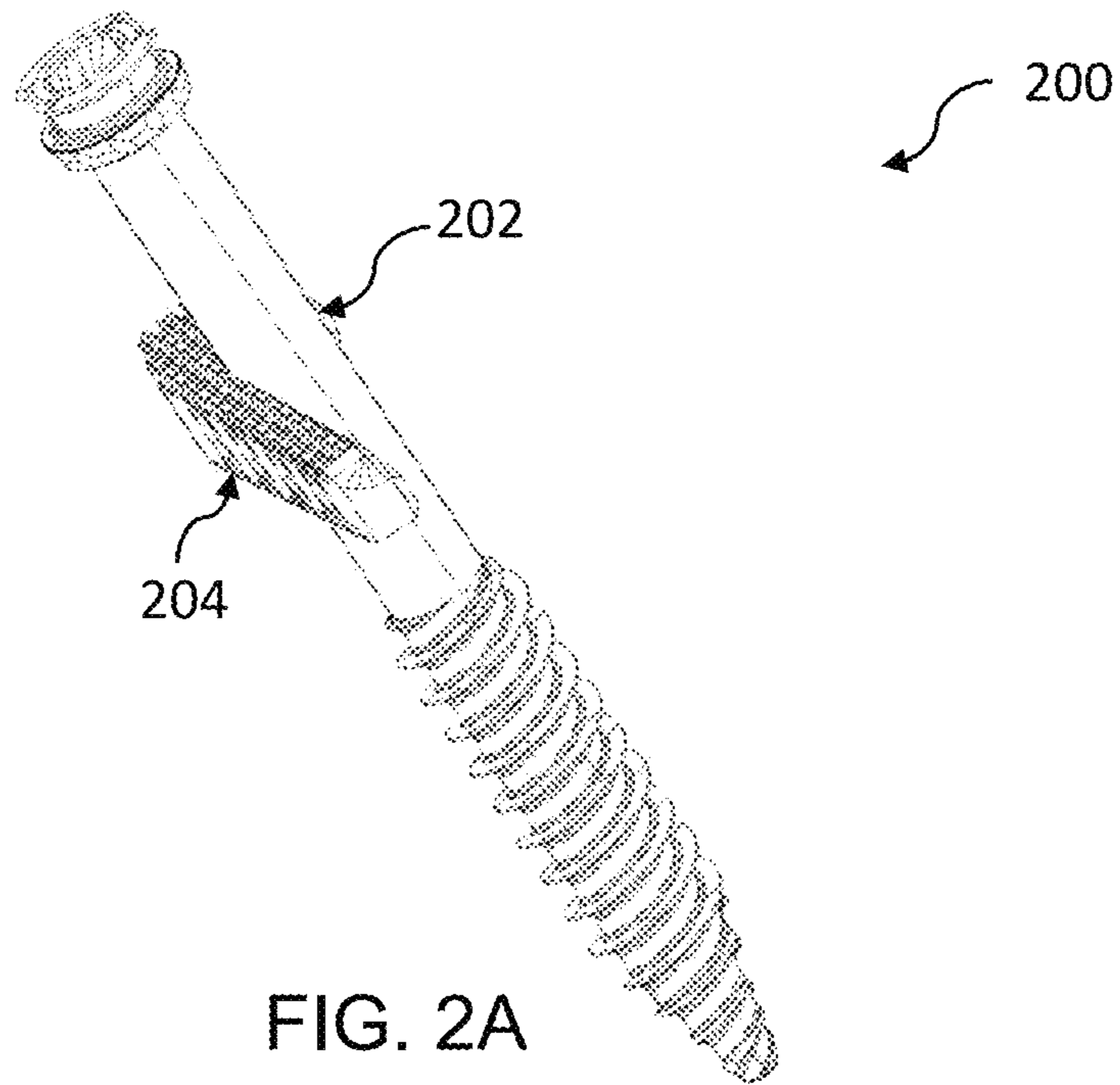


FIG. 1B



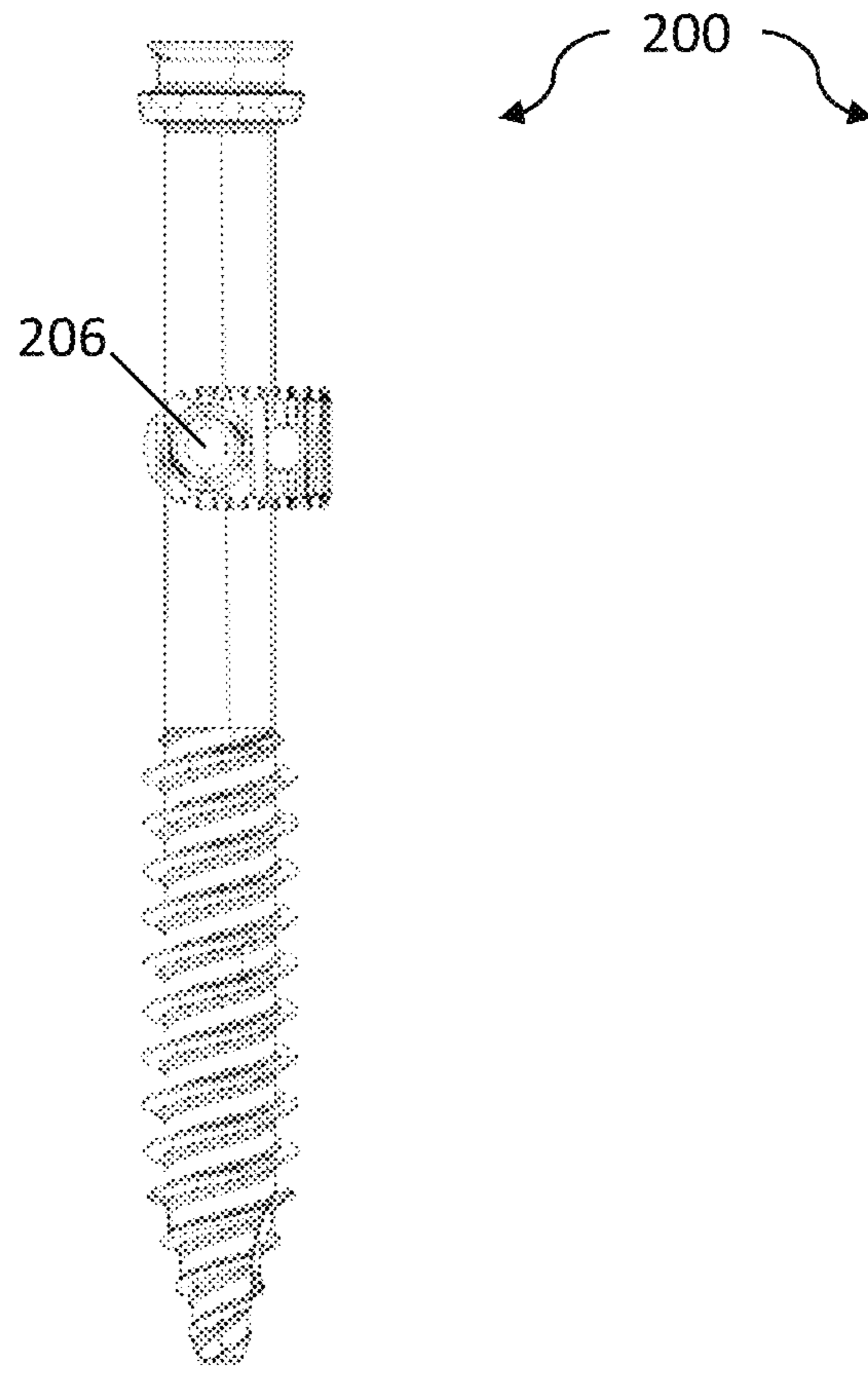


FIG. 2C

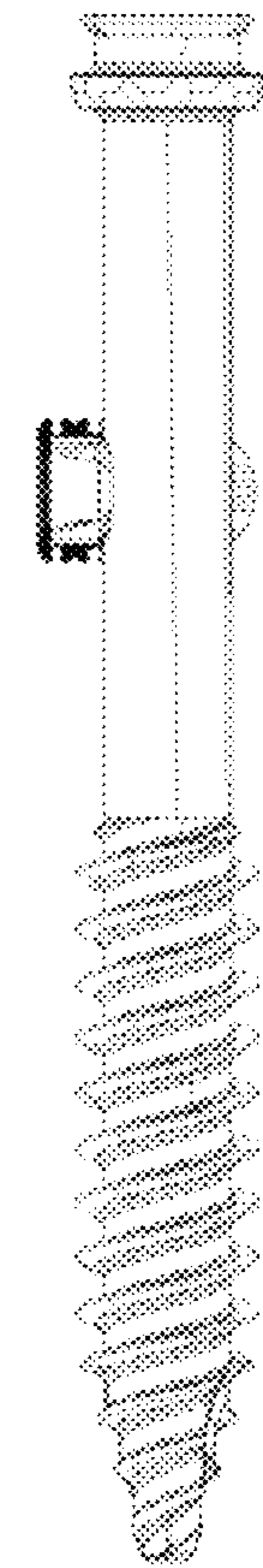


FIG. 2D

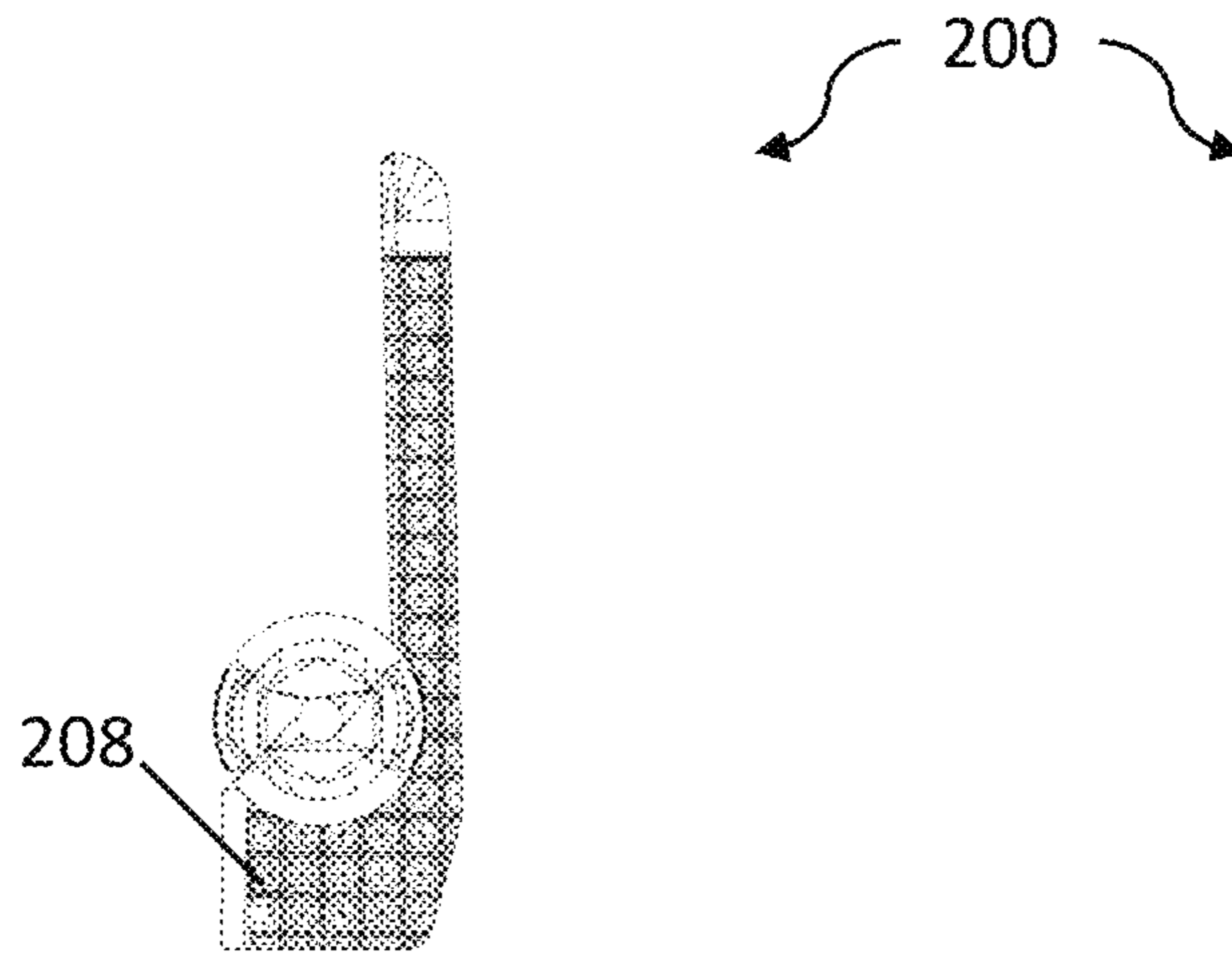


FIG. 2E

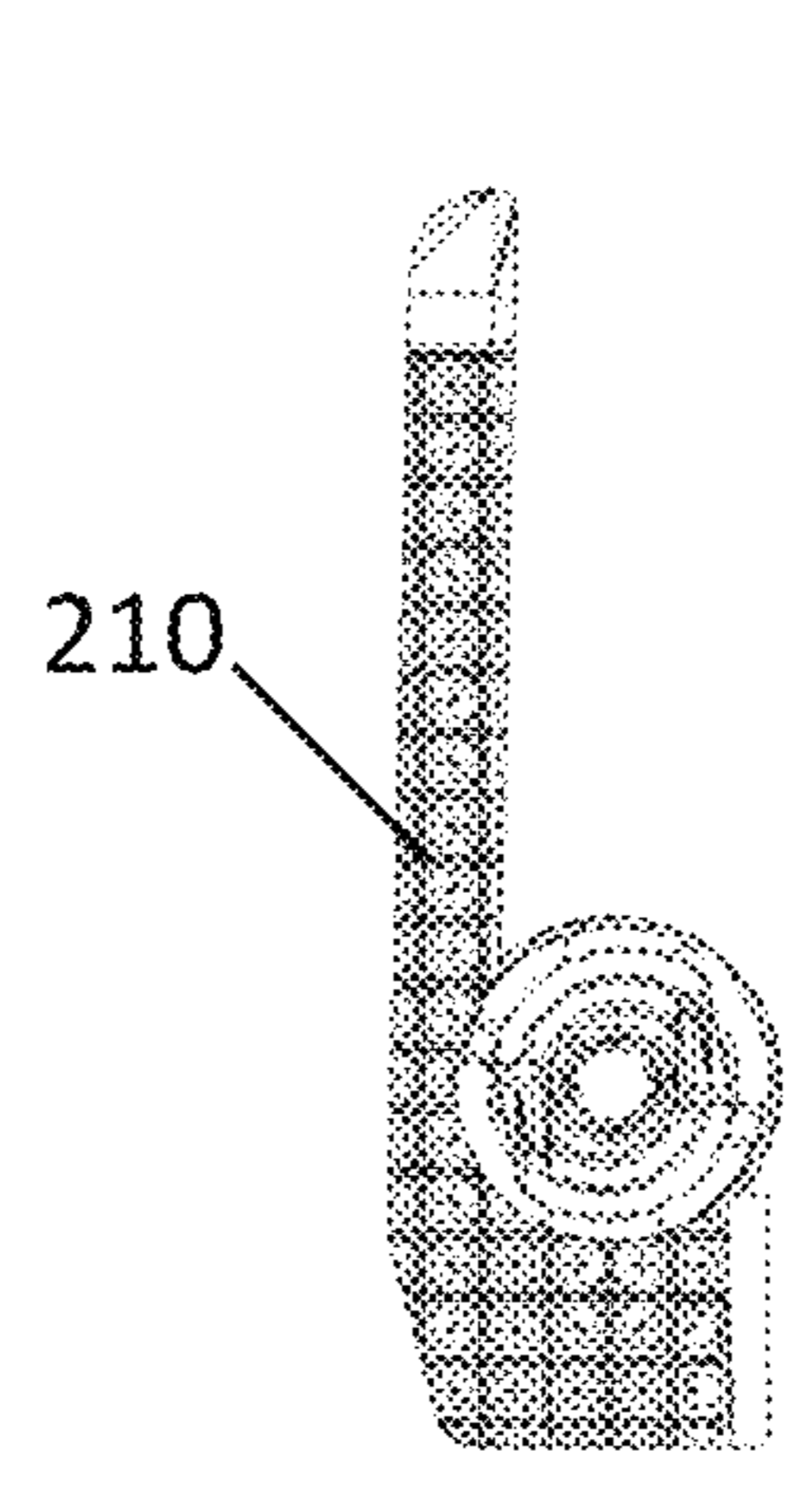


FIG. 2F

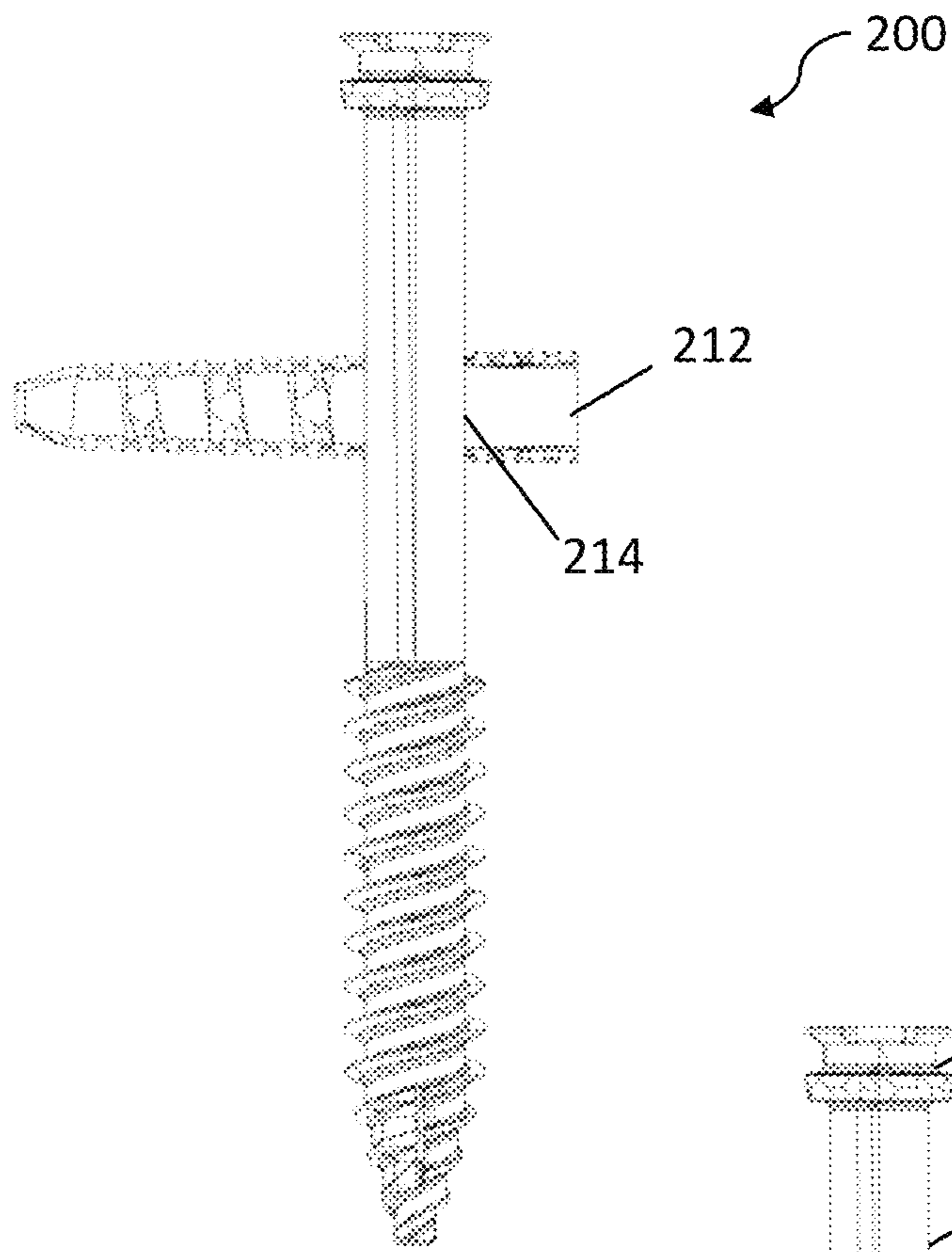


FIG. 2G

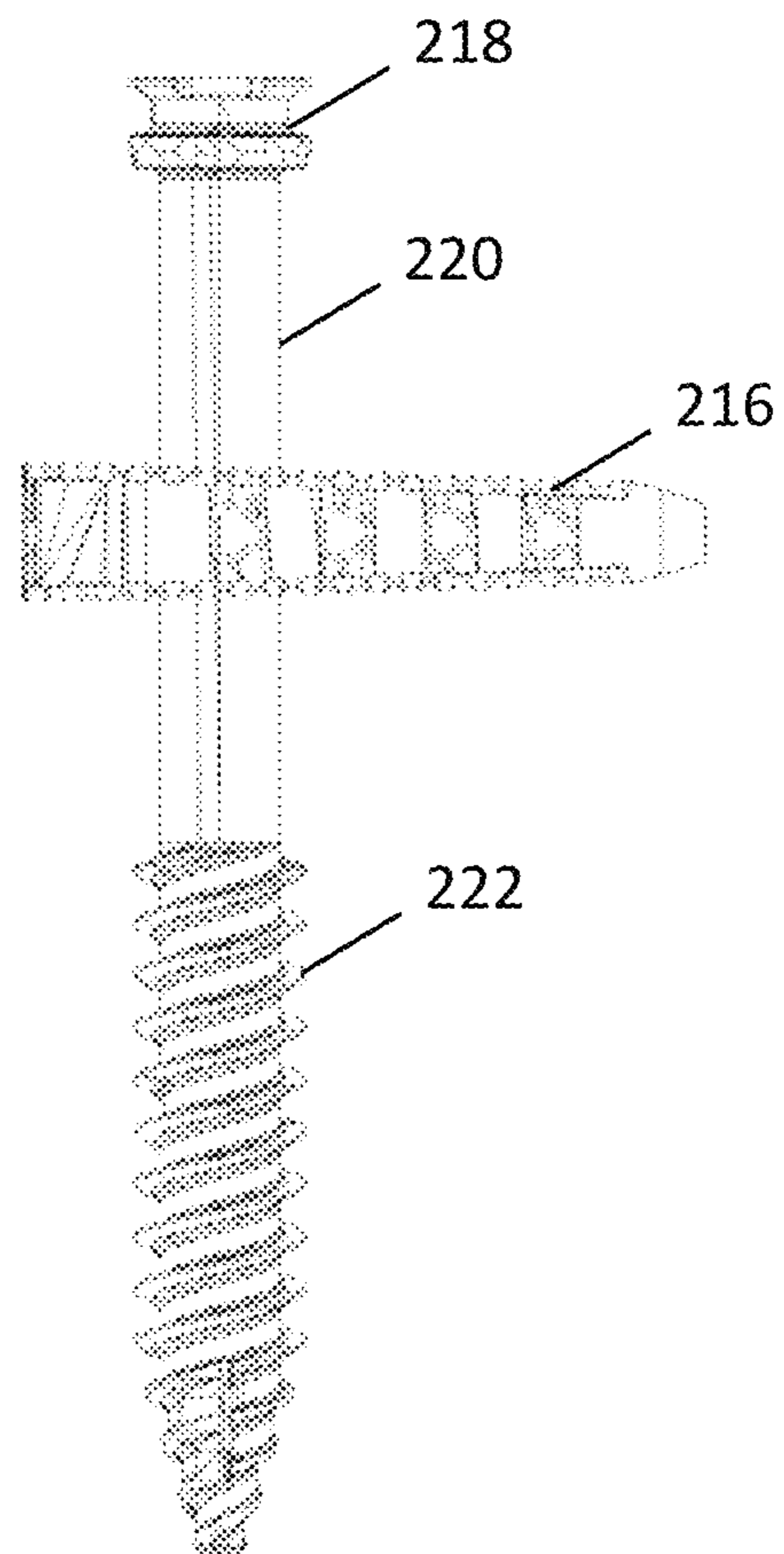


FIG. 2H

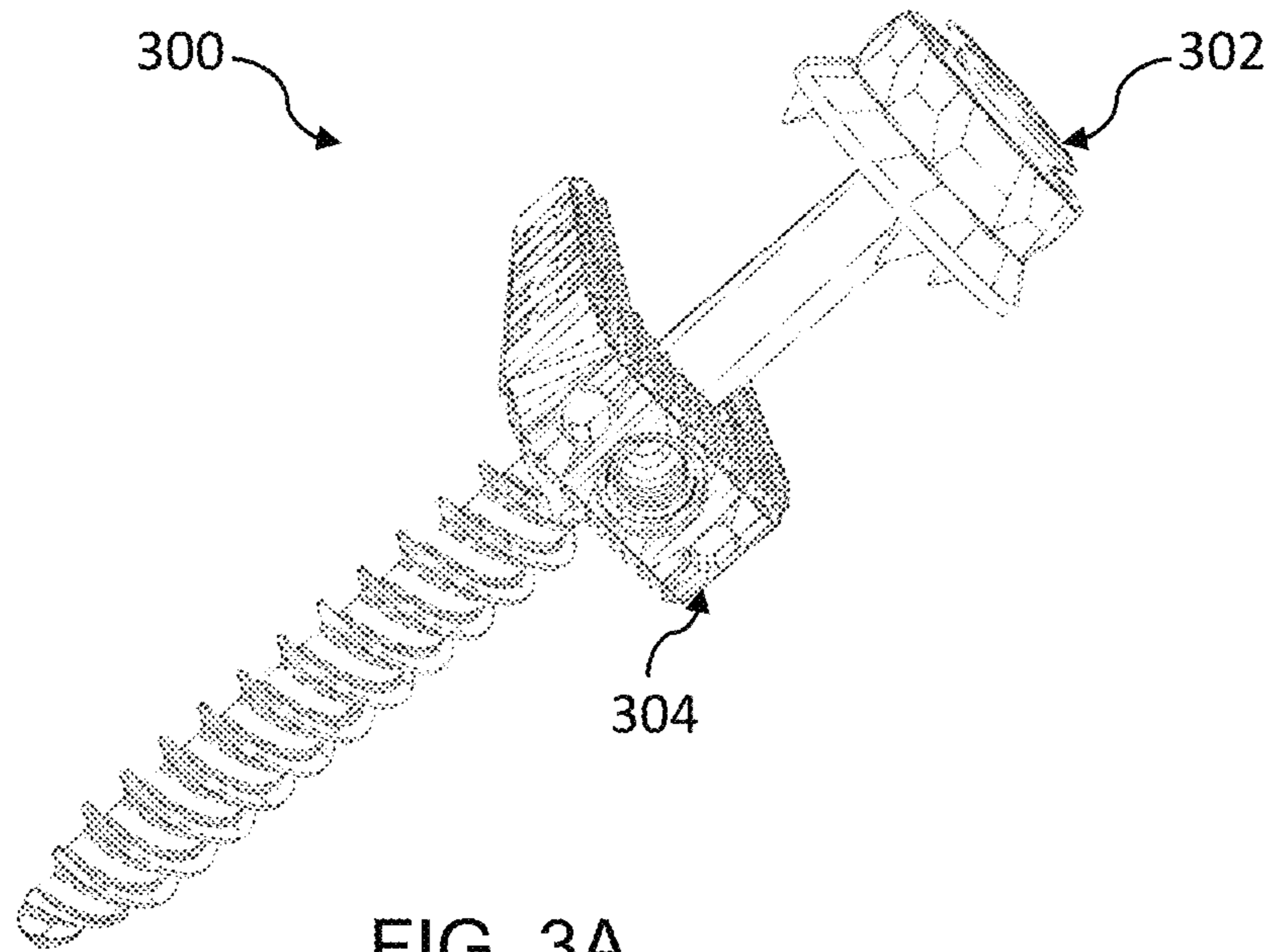


FIG. 3A

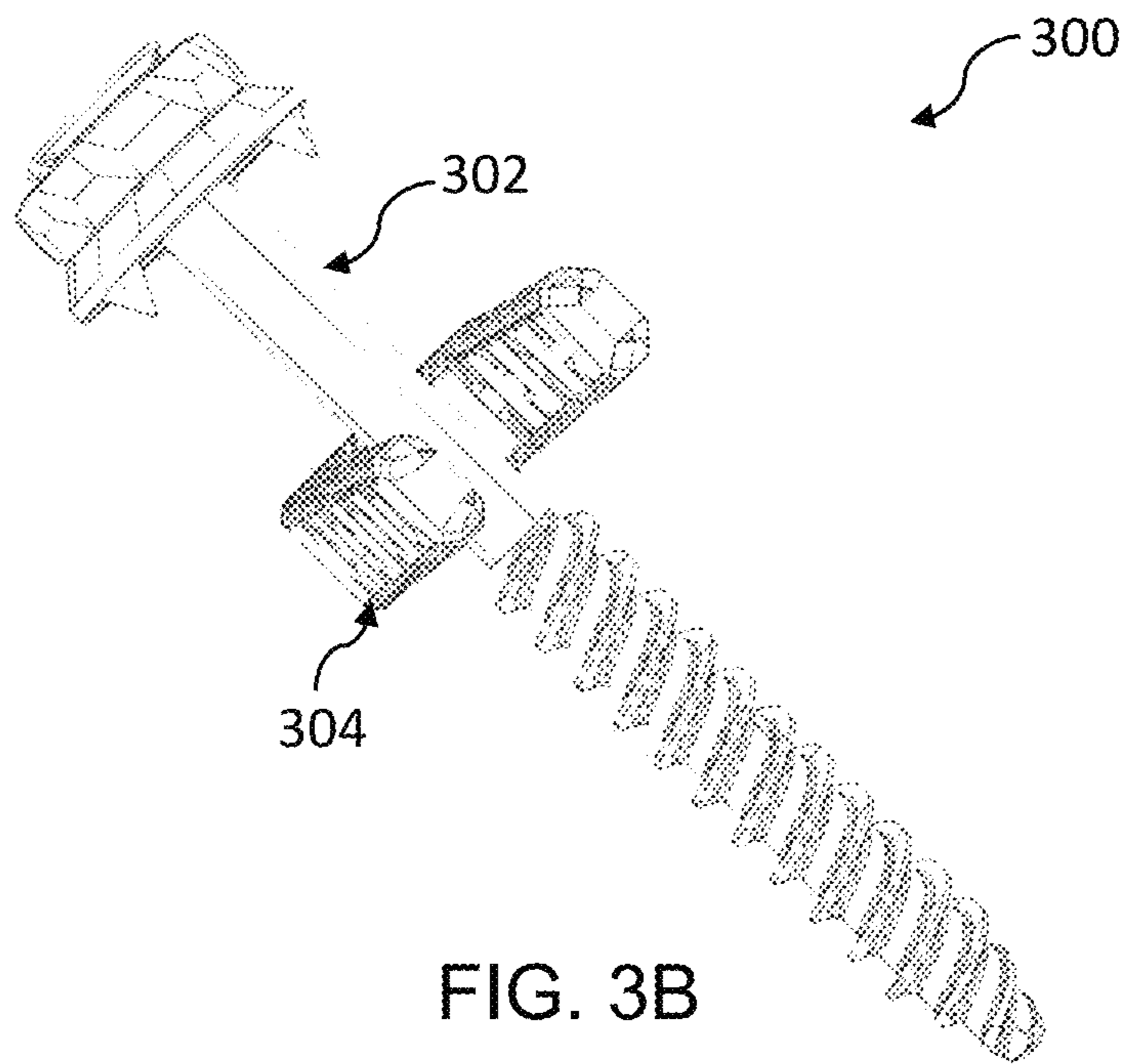


FIG. 3B

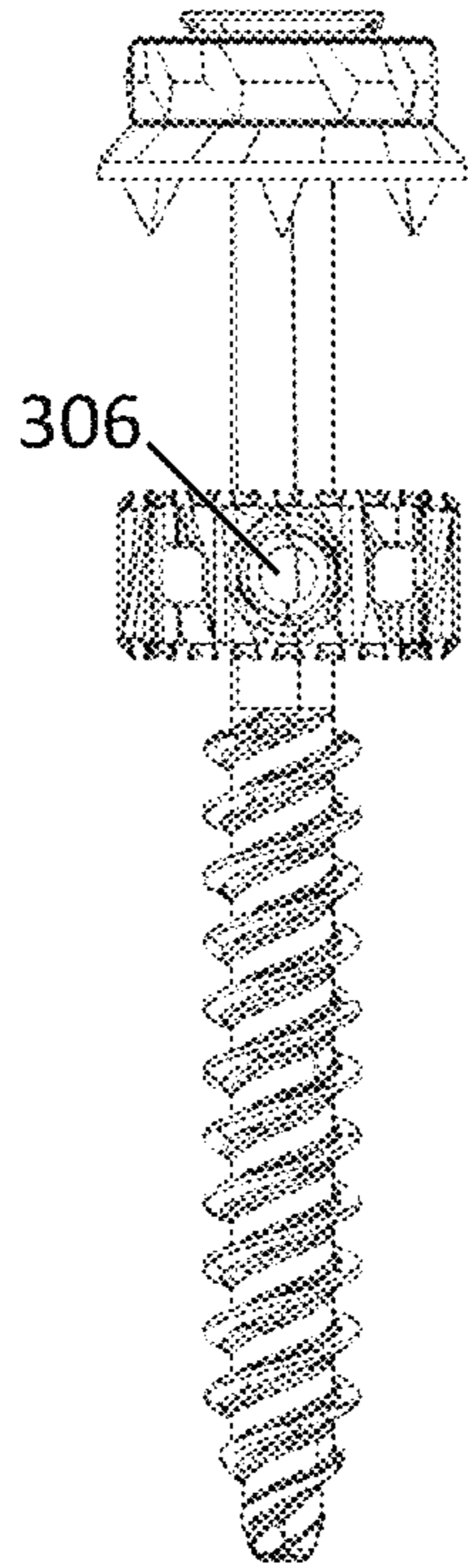


FIG. 3C

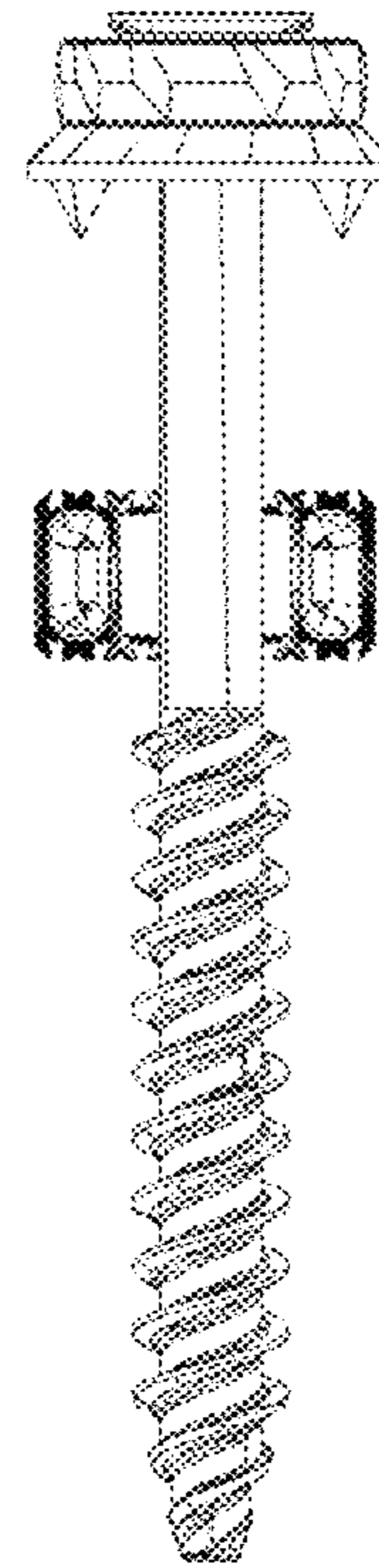
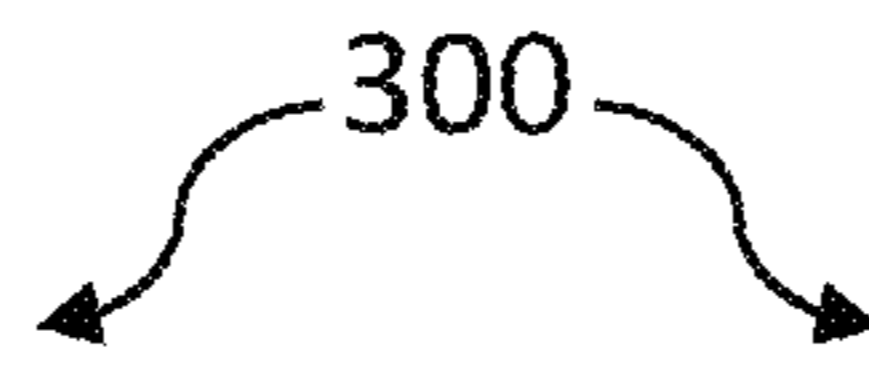


FIG. 3D

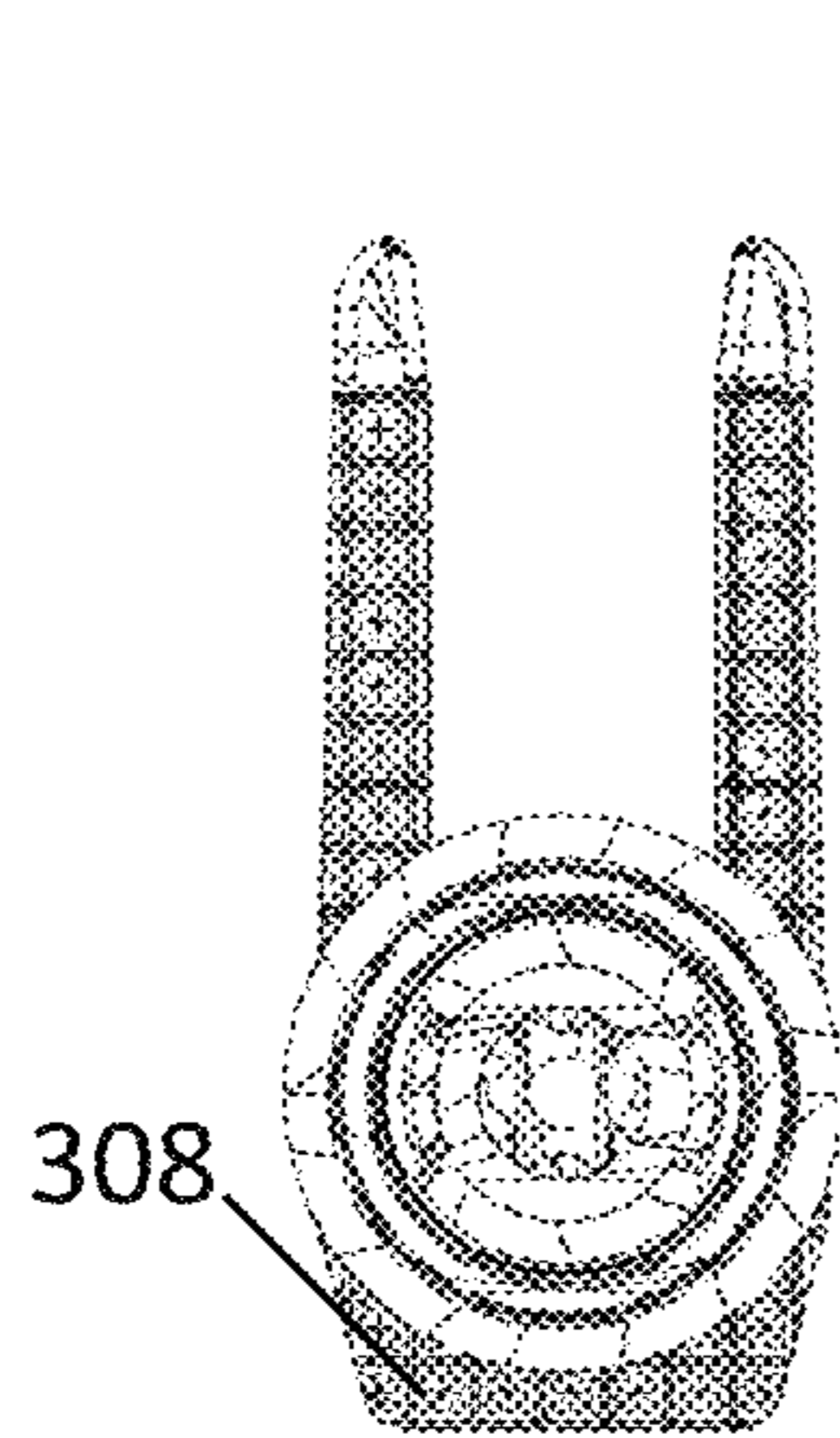


FIG. 3E

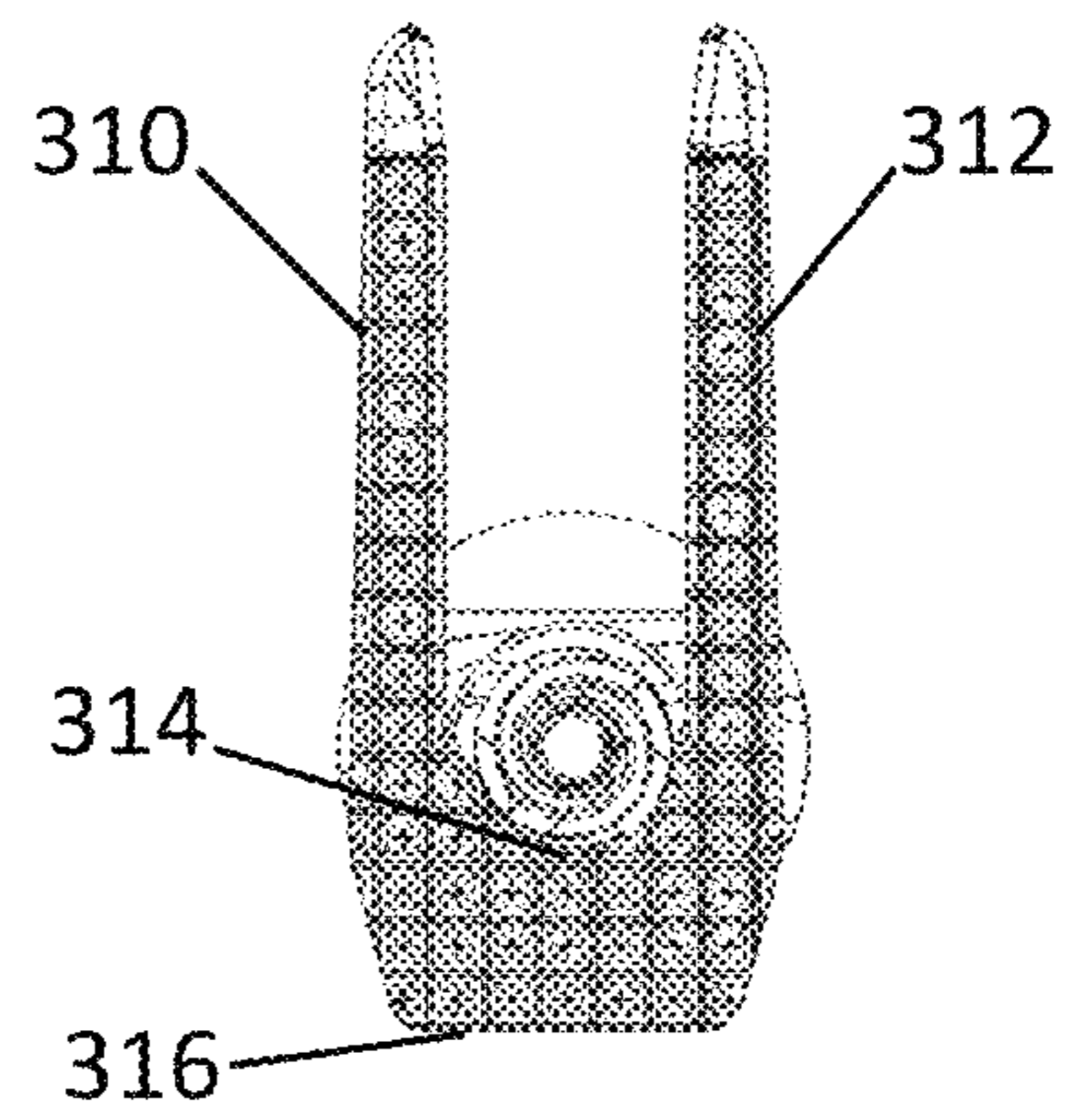
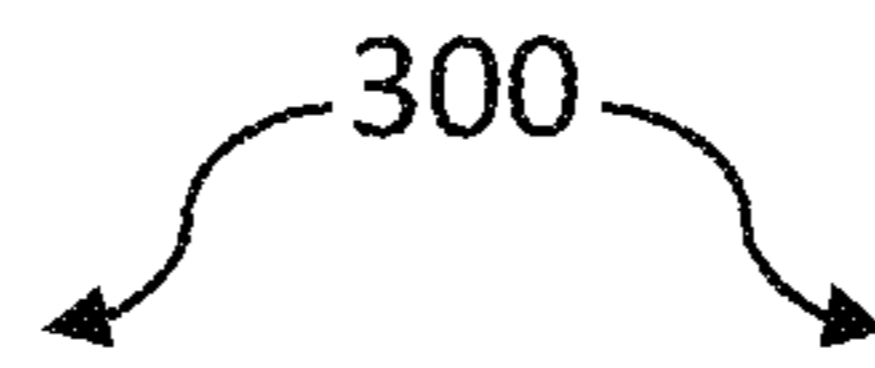


FIG. 3F

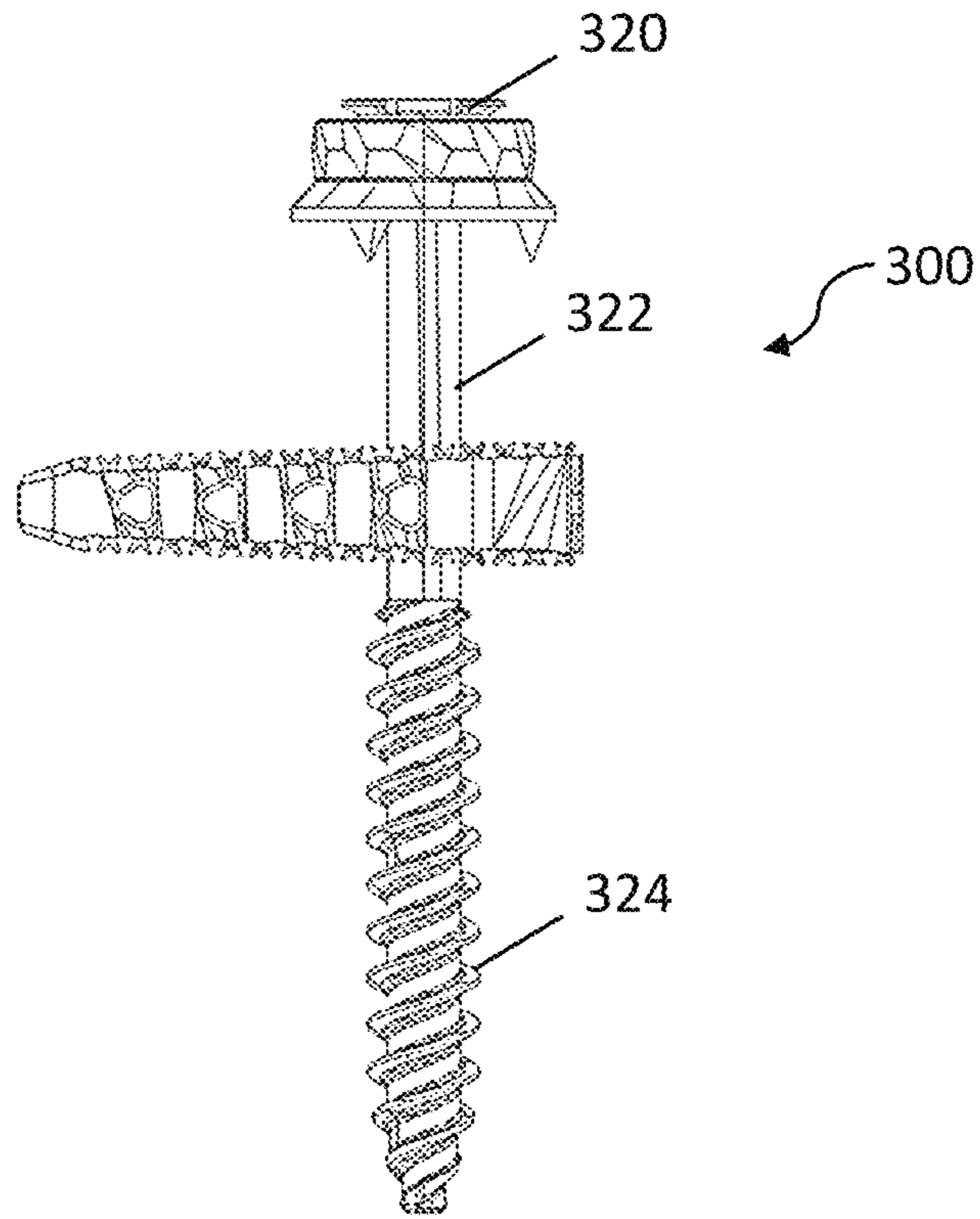


FIG. 3G

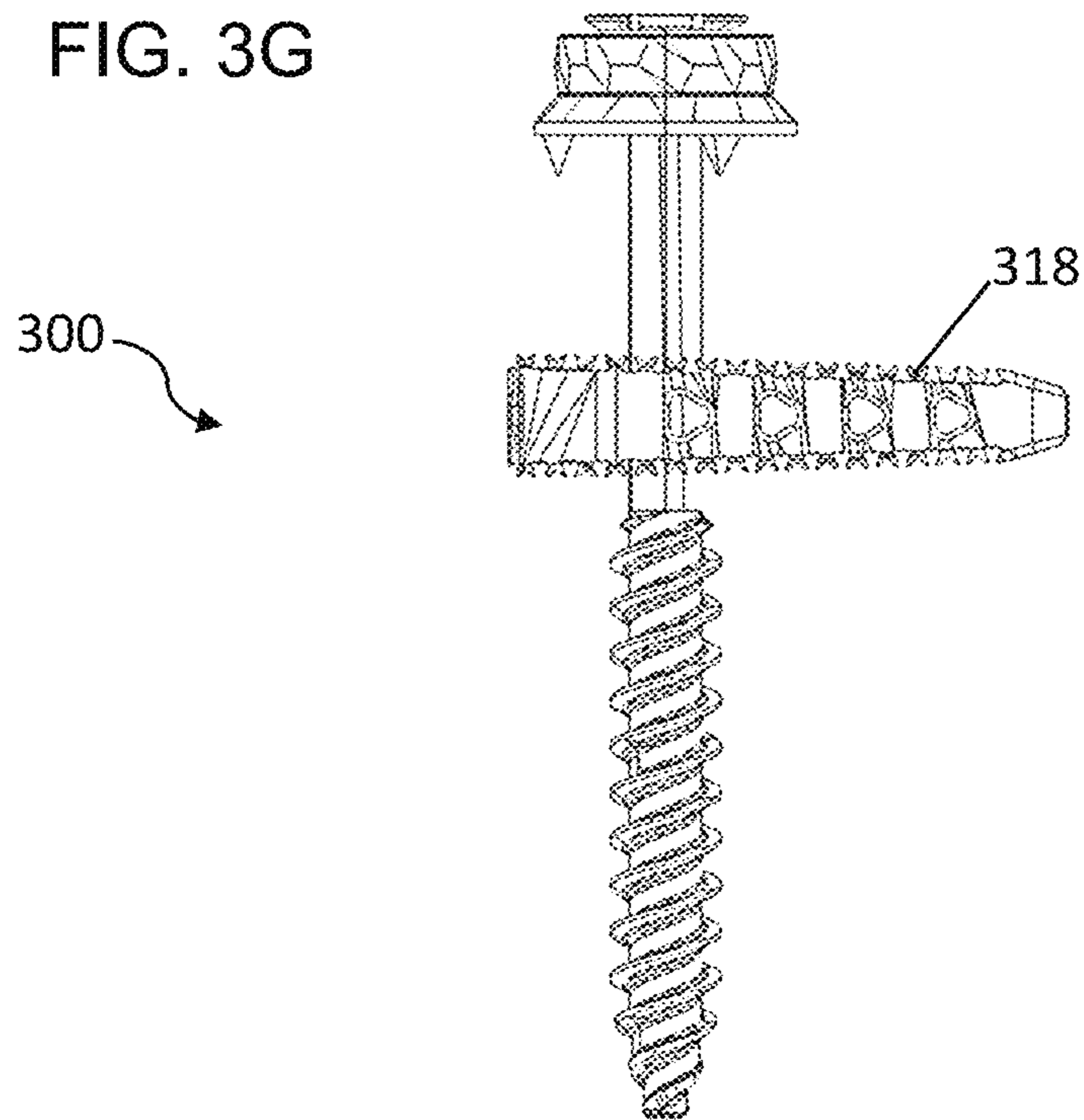


FIG. 3H

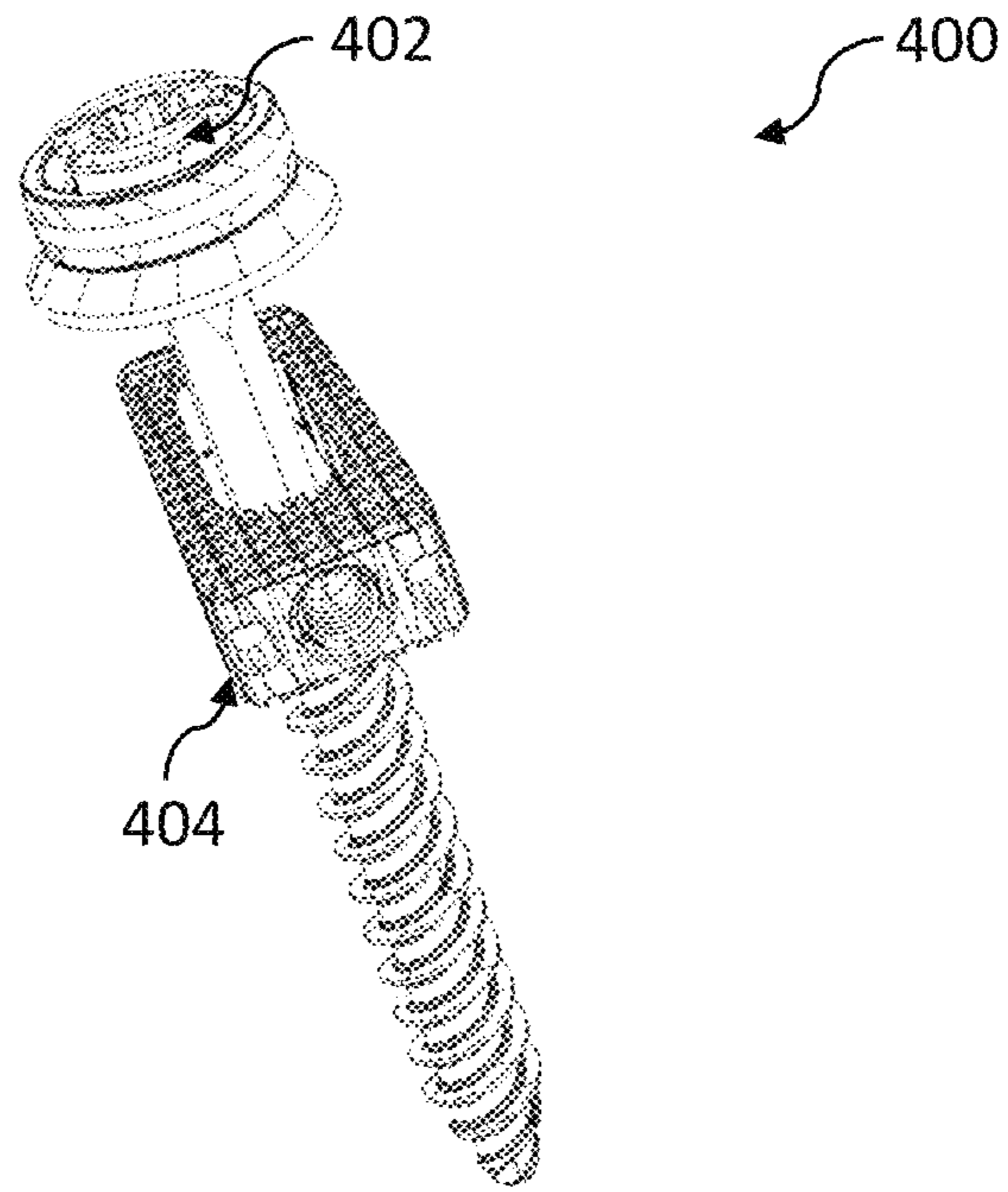


FIG. 4A

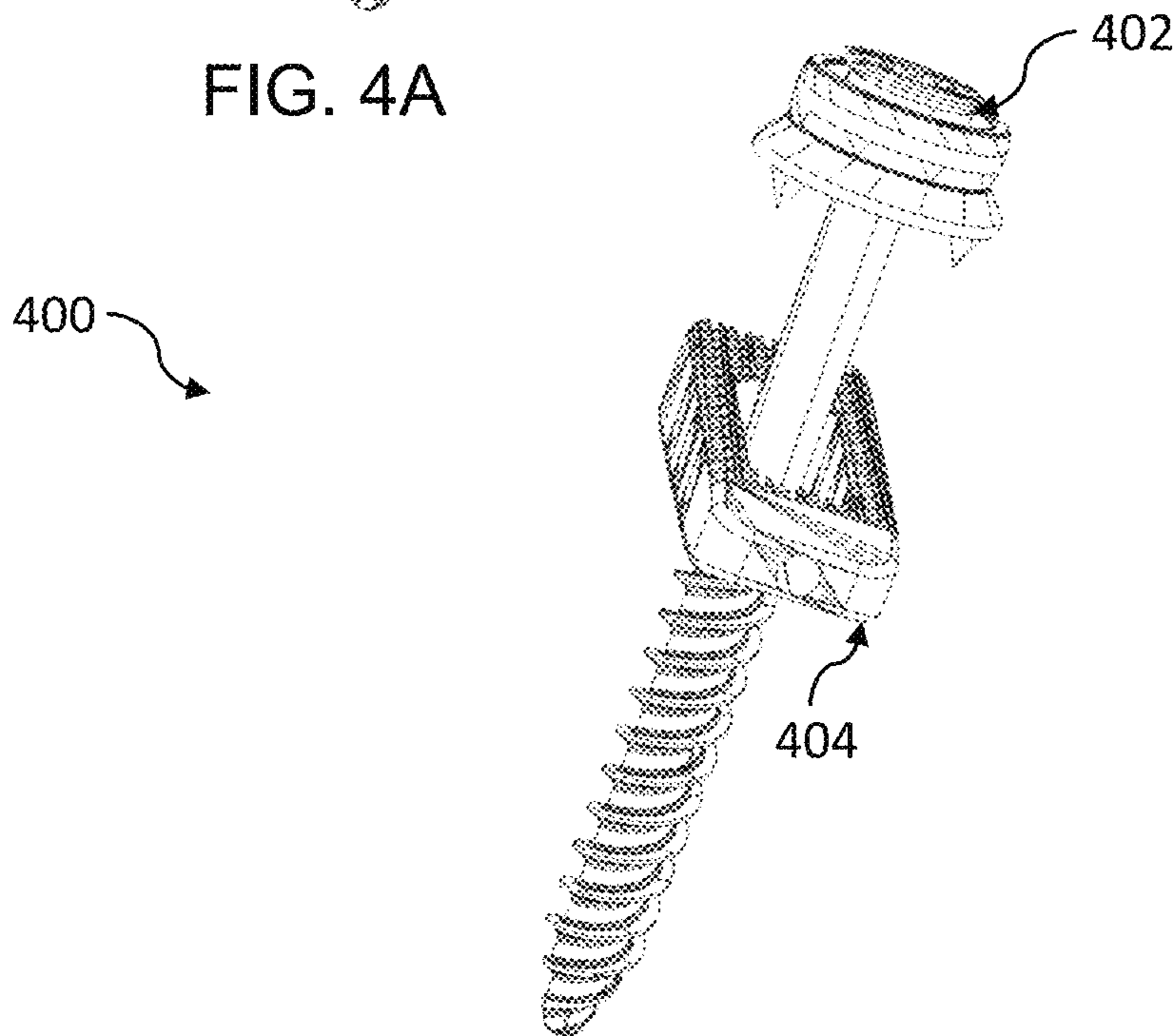


FIG. 4B

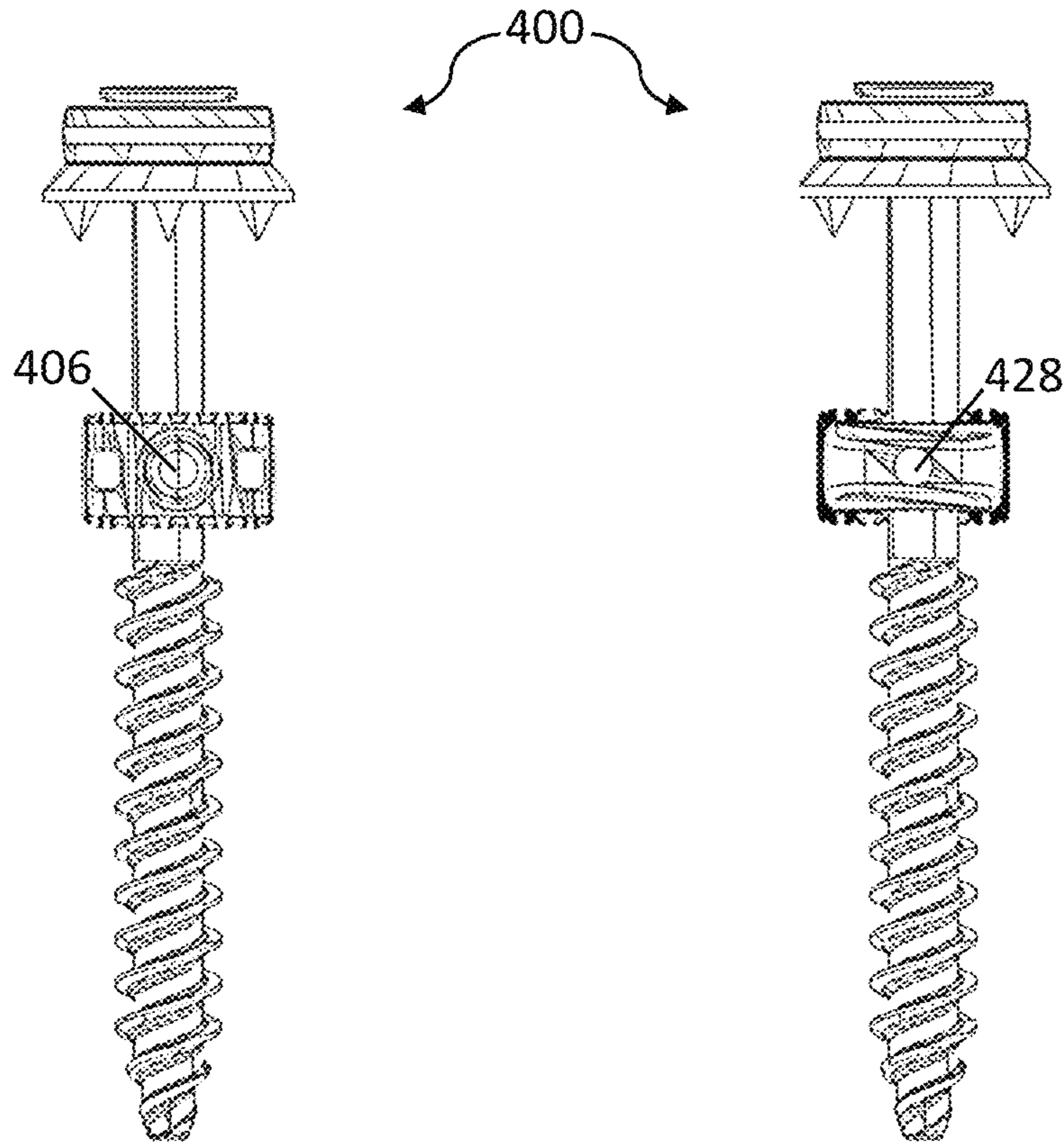


FIG. 4C

FIG. 4D

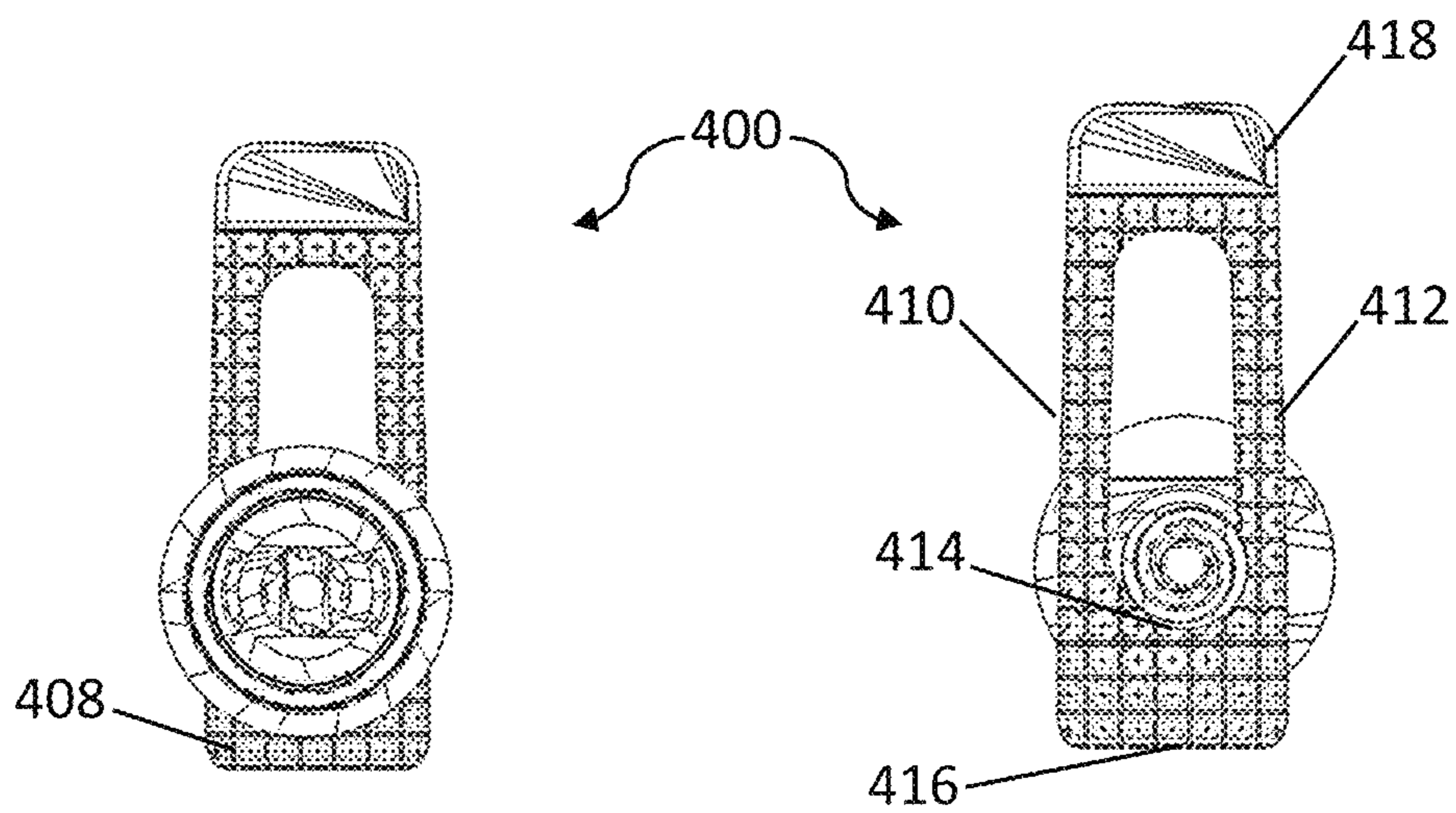


FIG. 4E

FIG. 4F

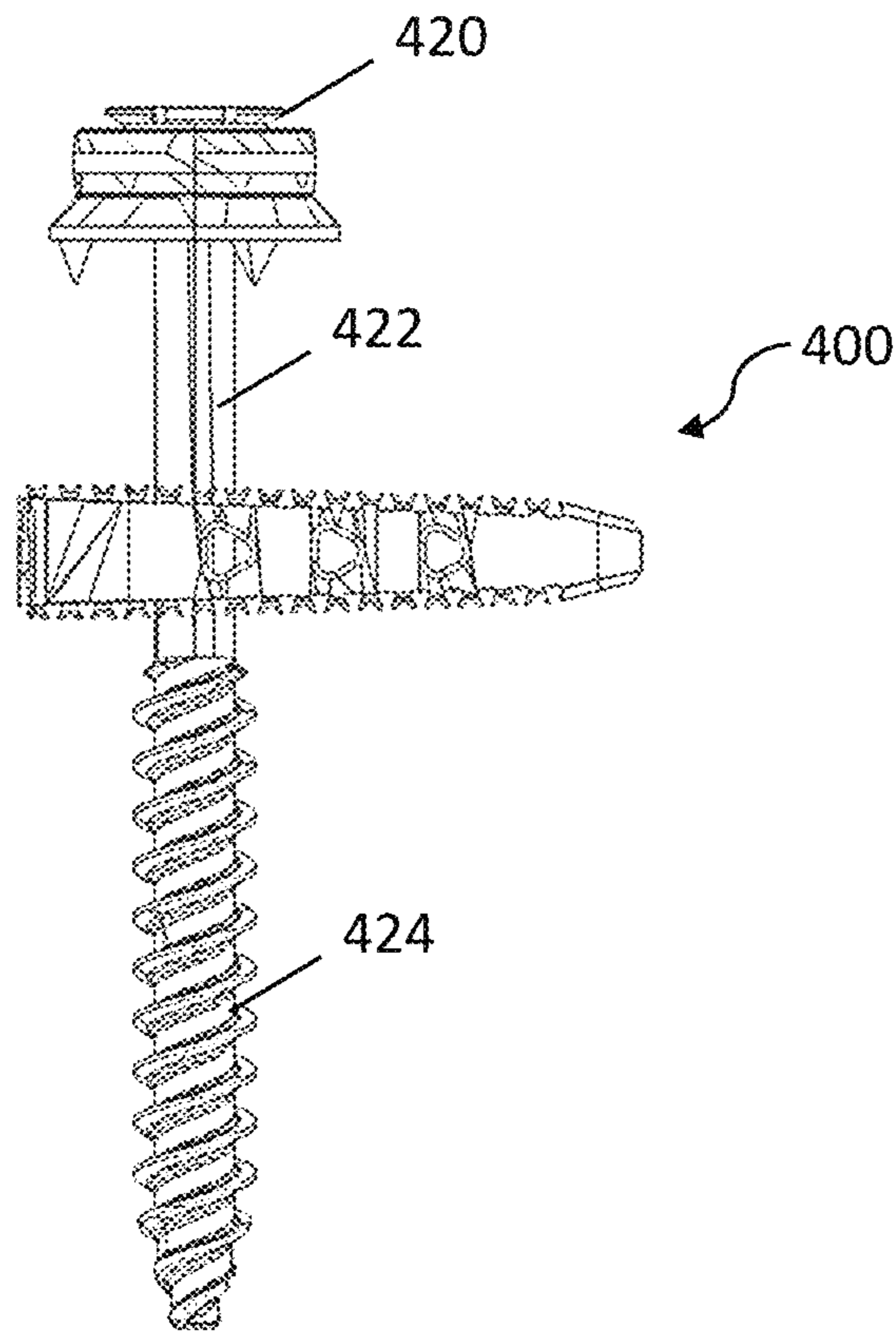


FIG. 4G

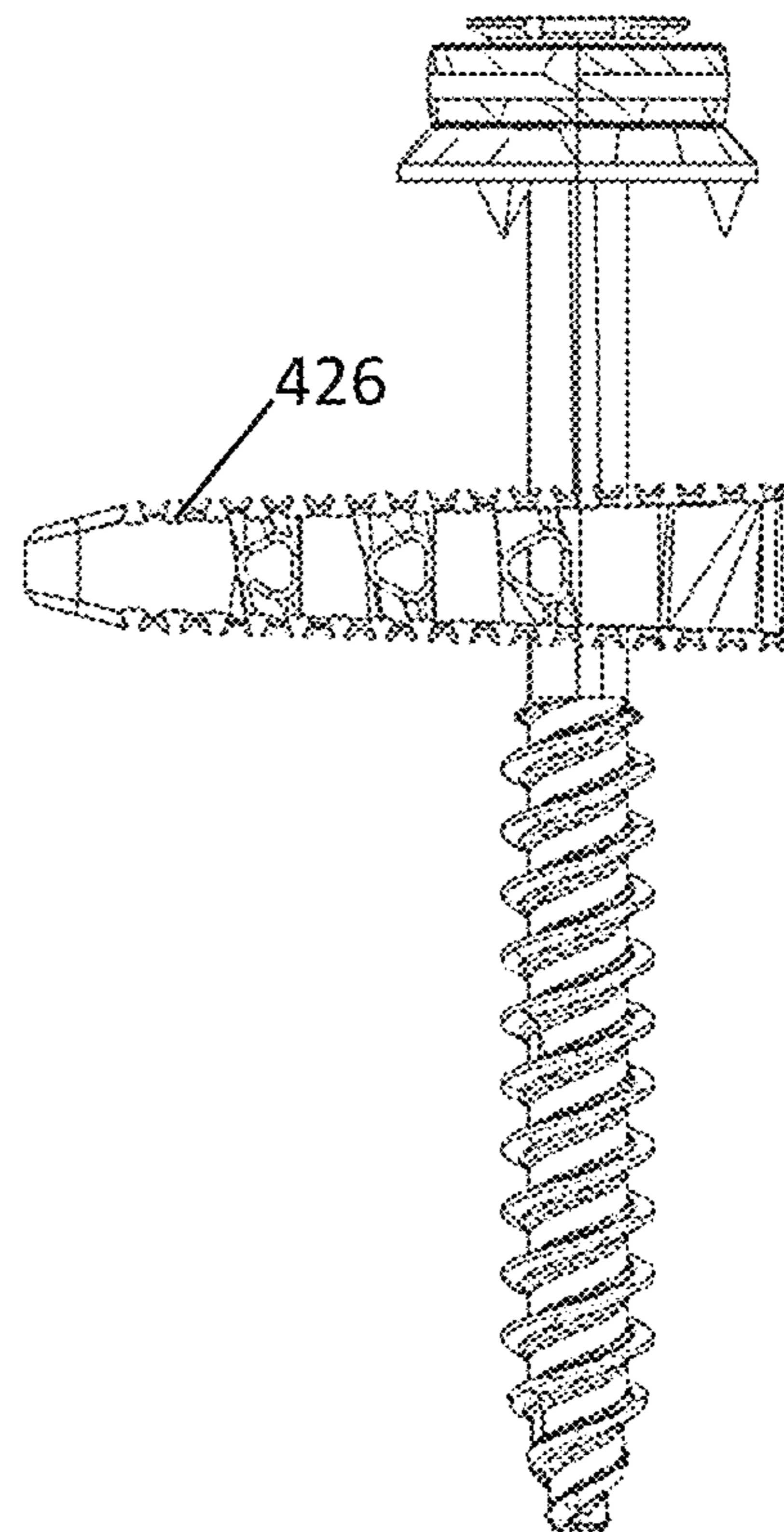
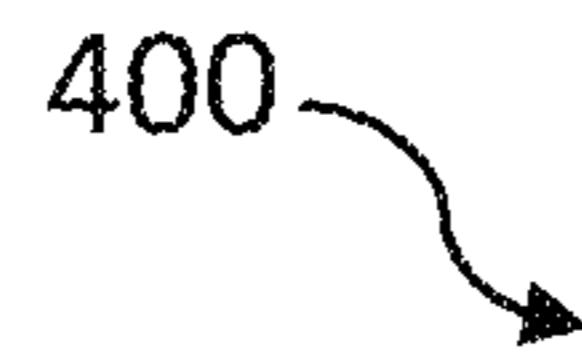


FIG. 4H

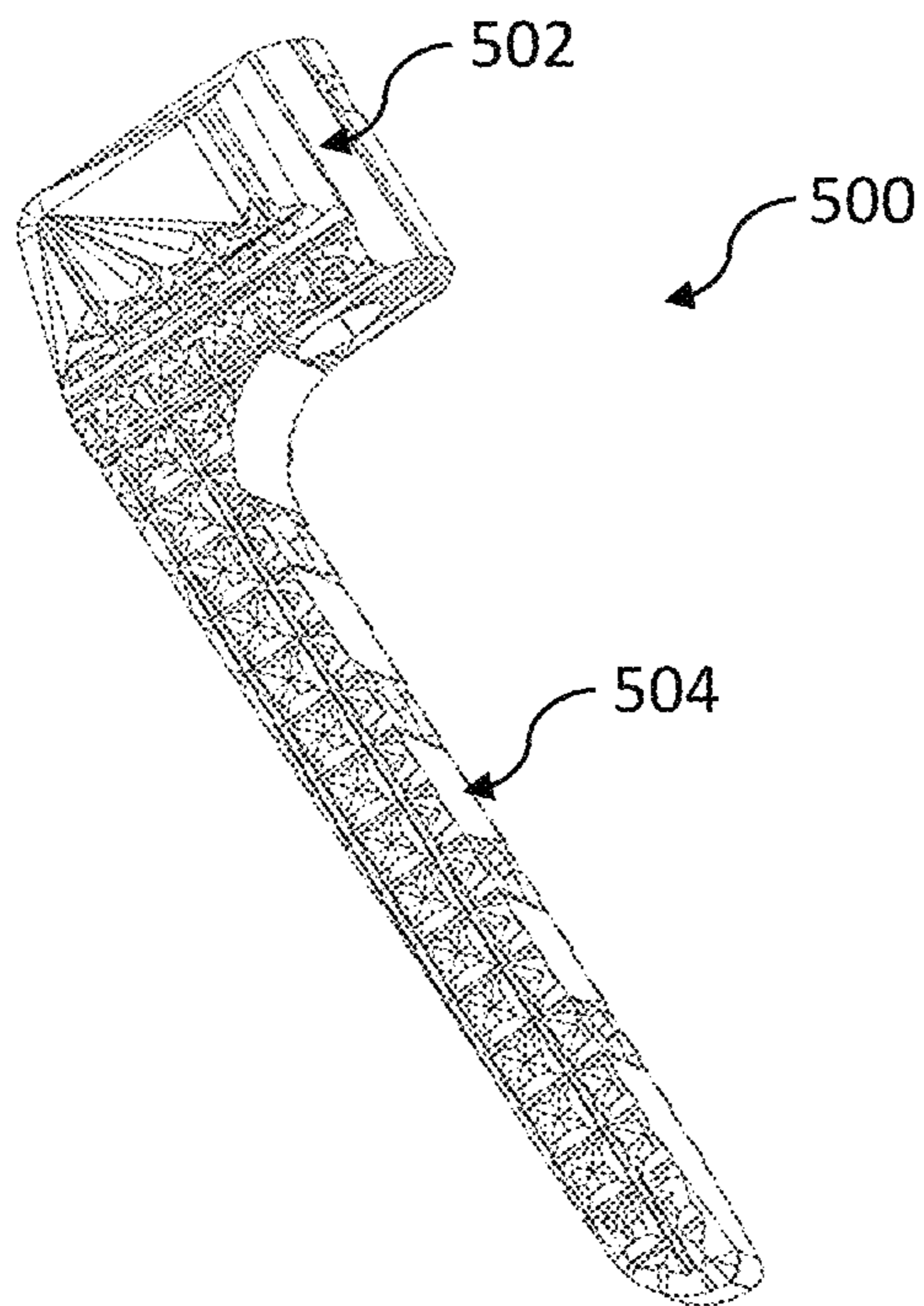


FIG. 5A

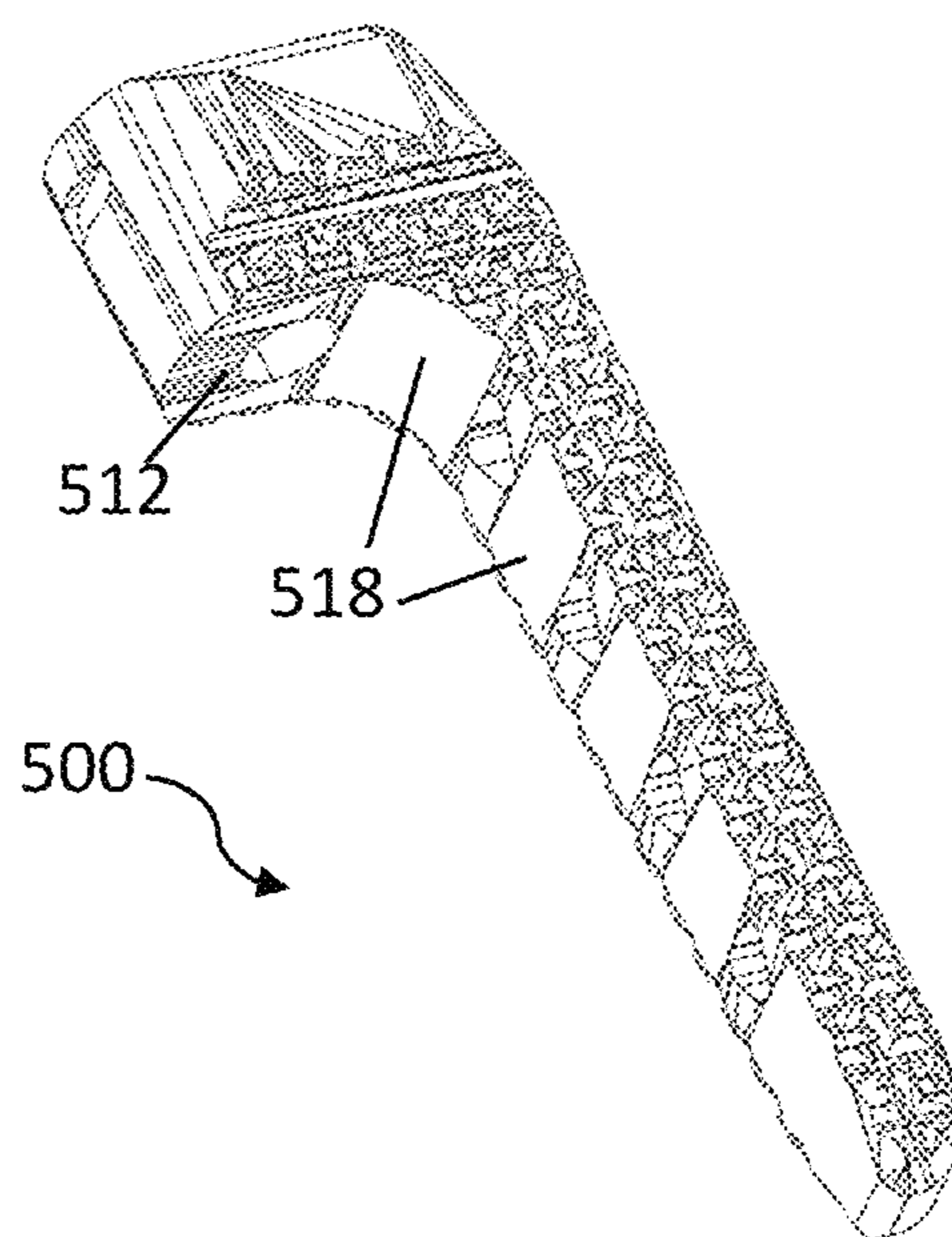


FIG. 5B

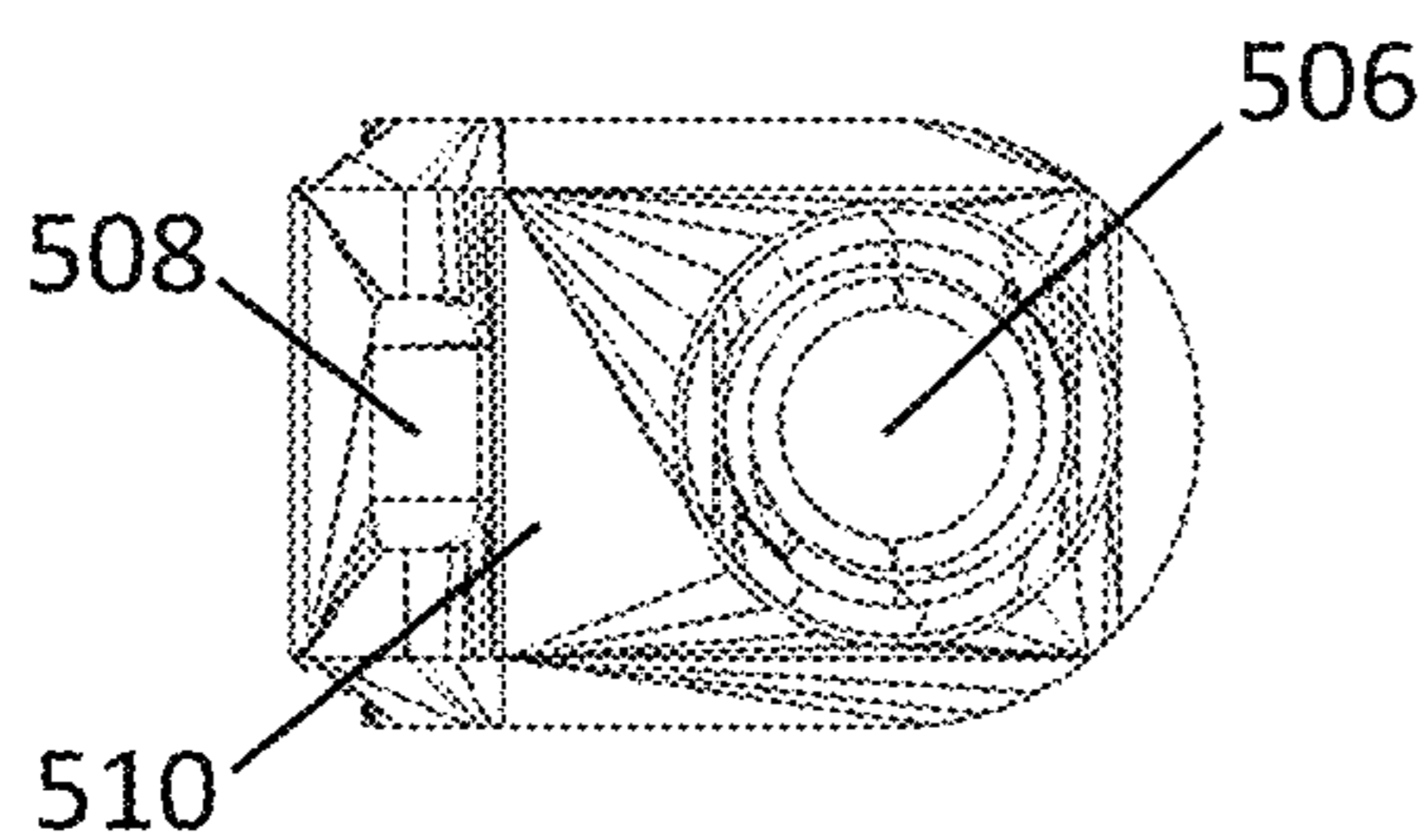


FIG. 5C

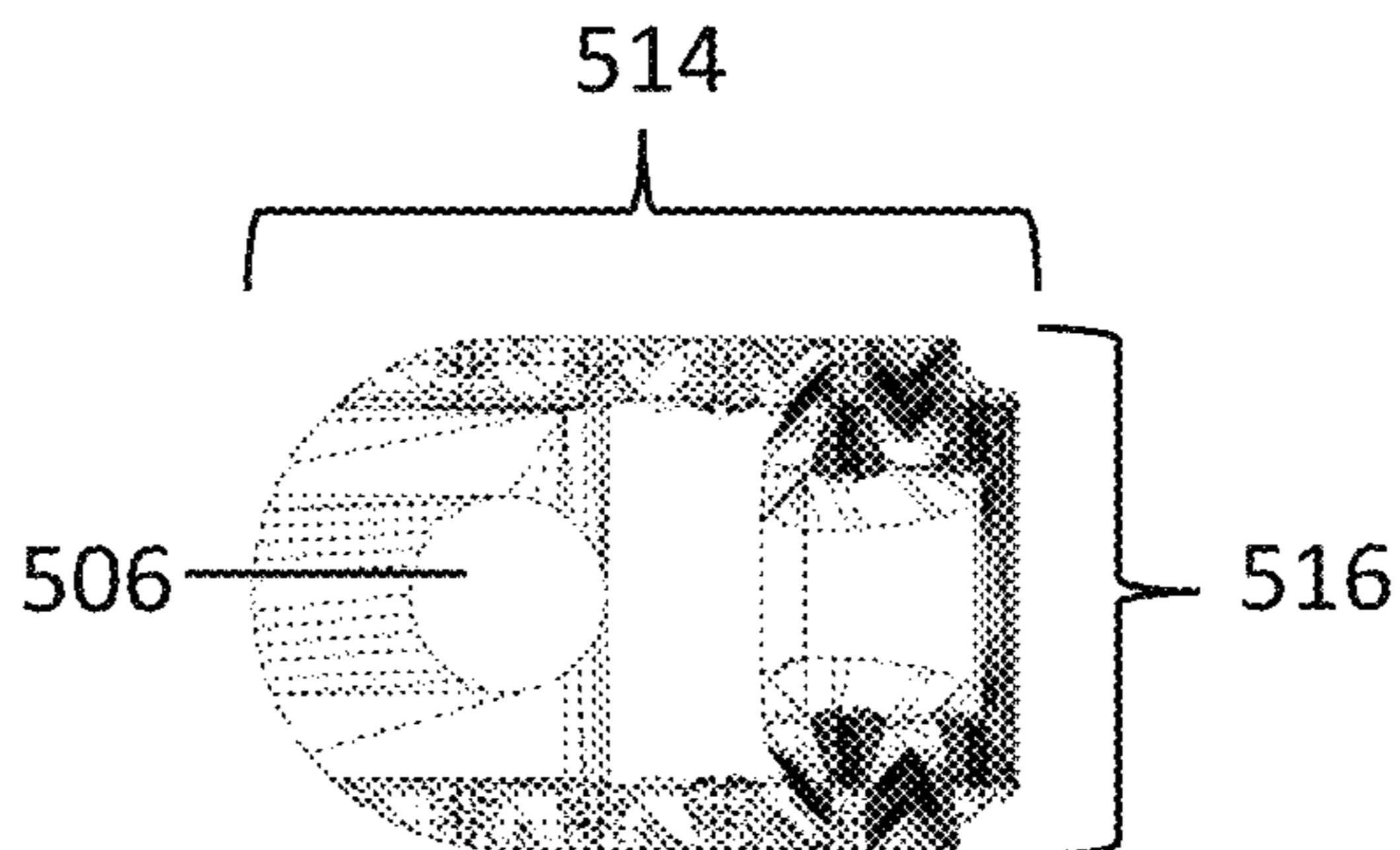


FIG. 5D

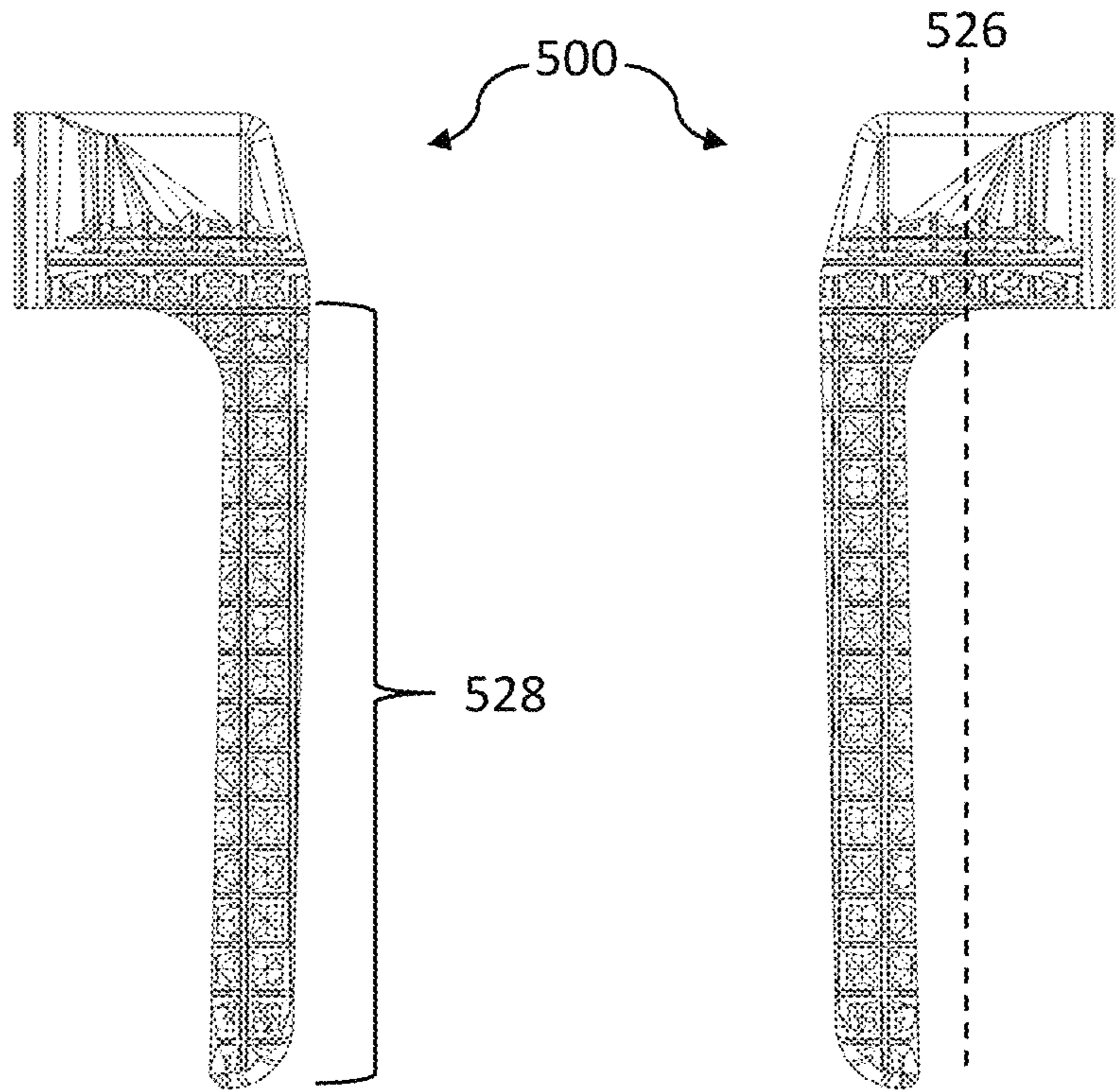


FIG. 5E

FIG. 5F

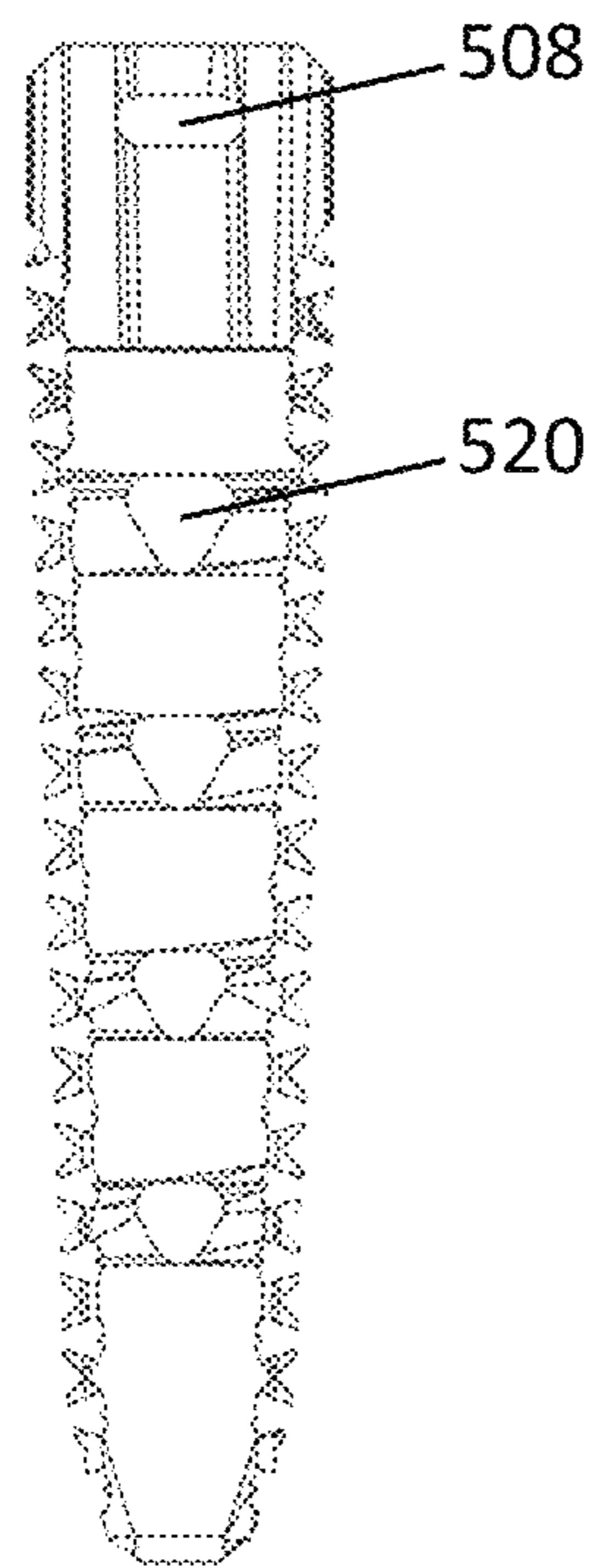


FIG. 5G

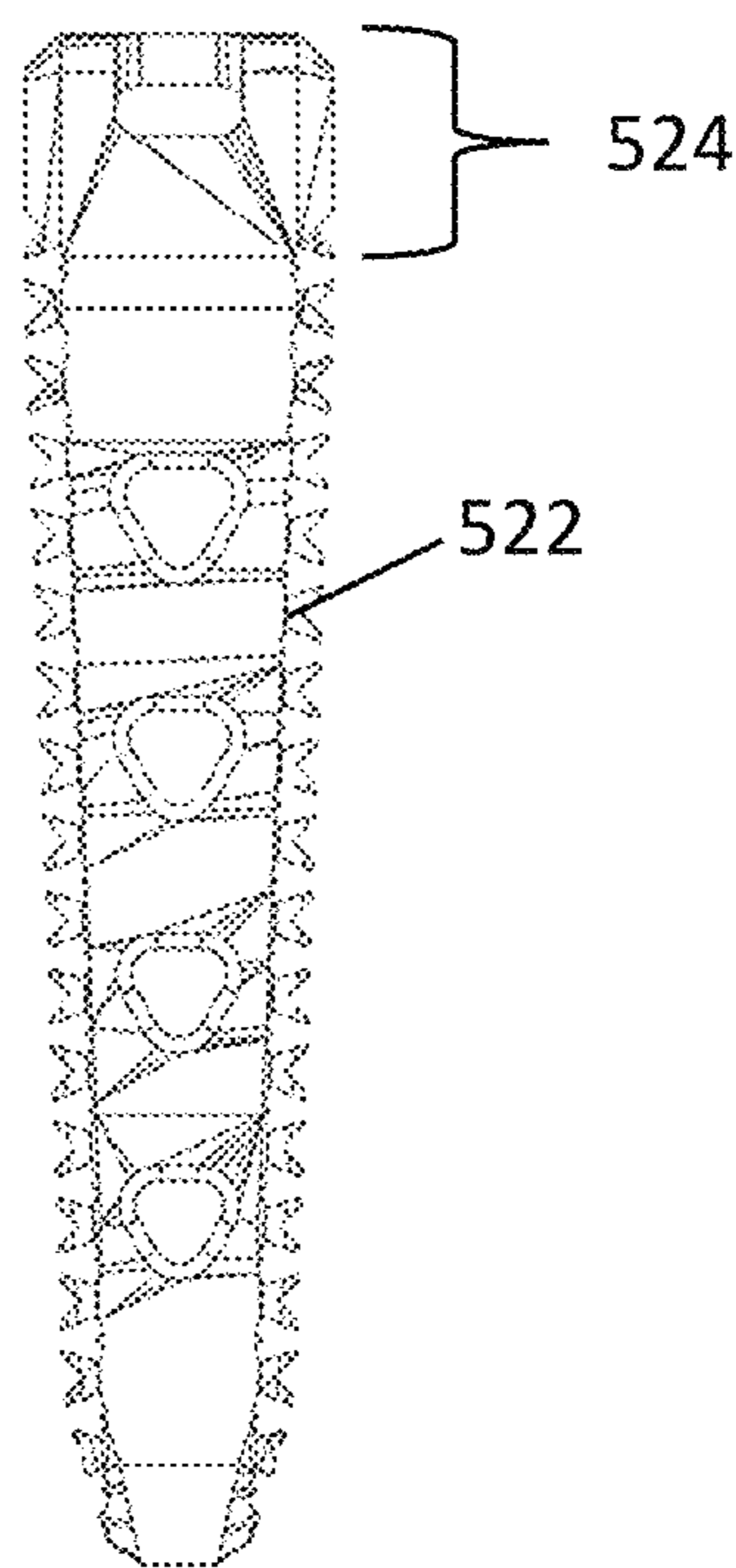


FIG. 5H

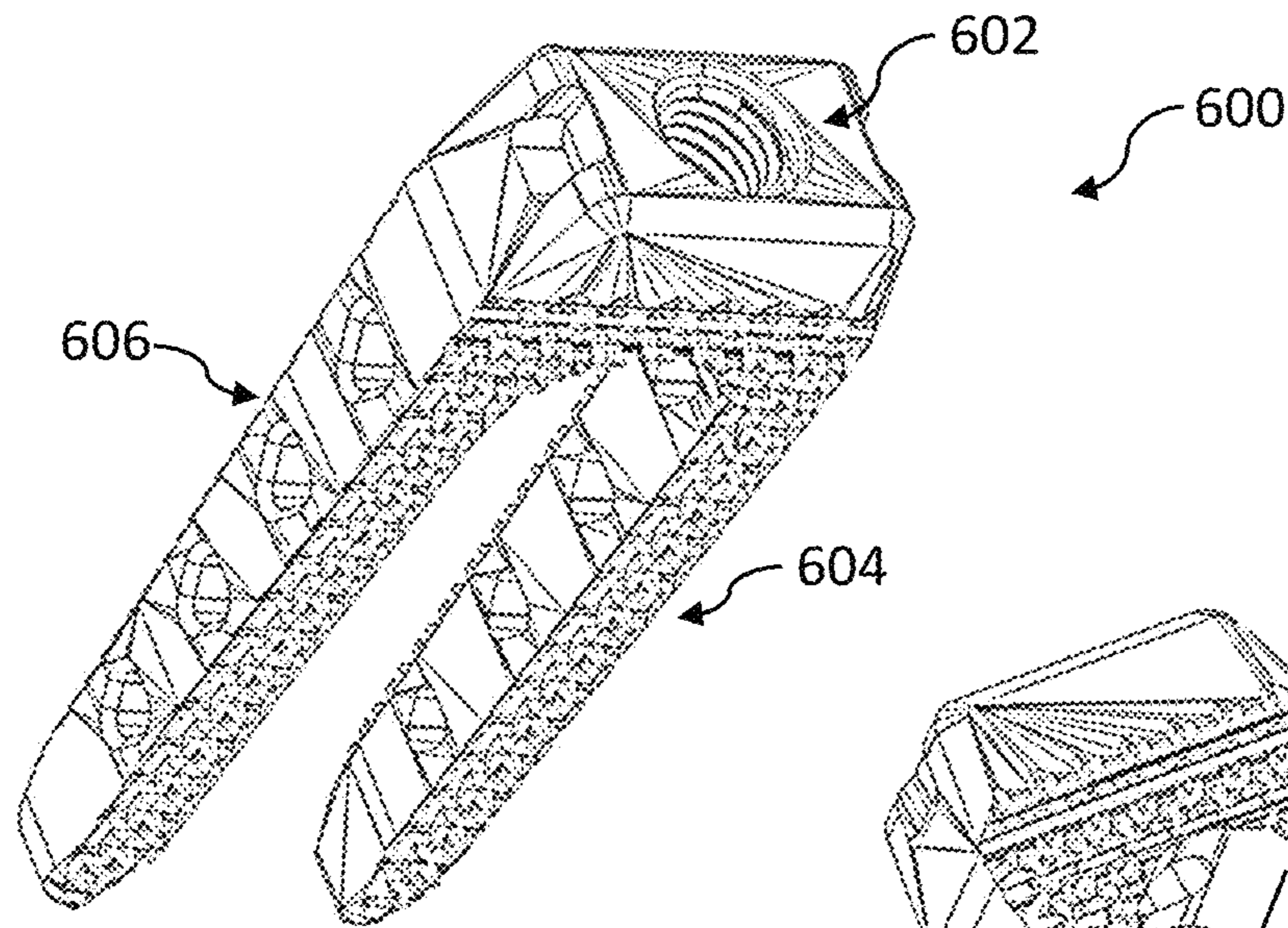


FIG. 6A

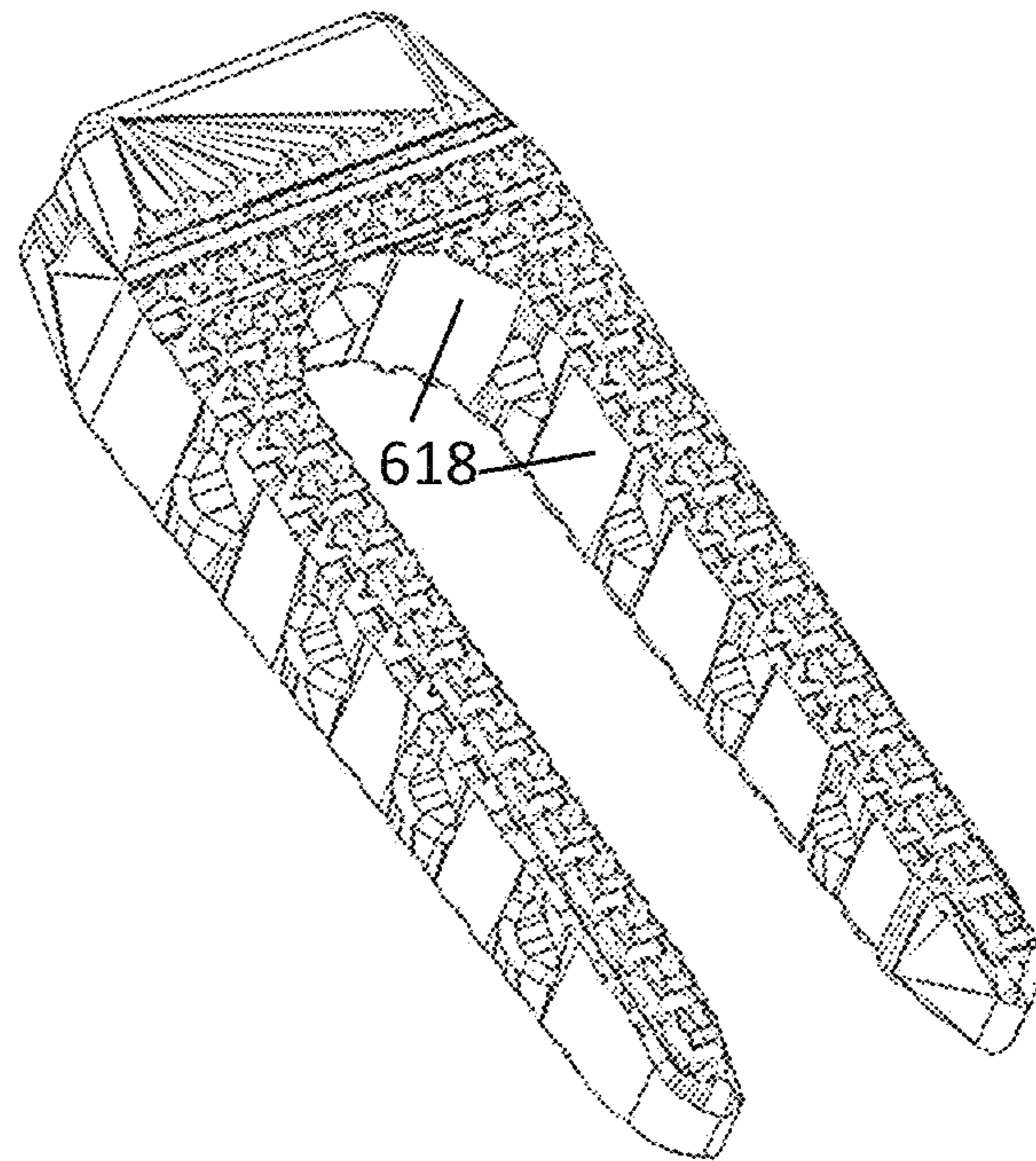


FIG. 6B

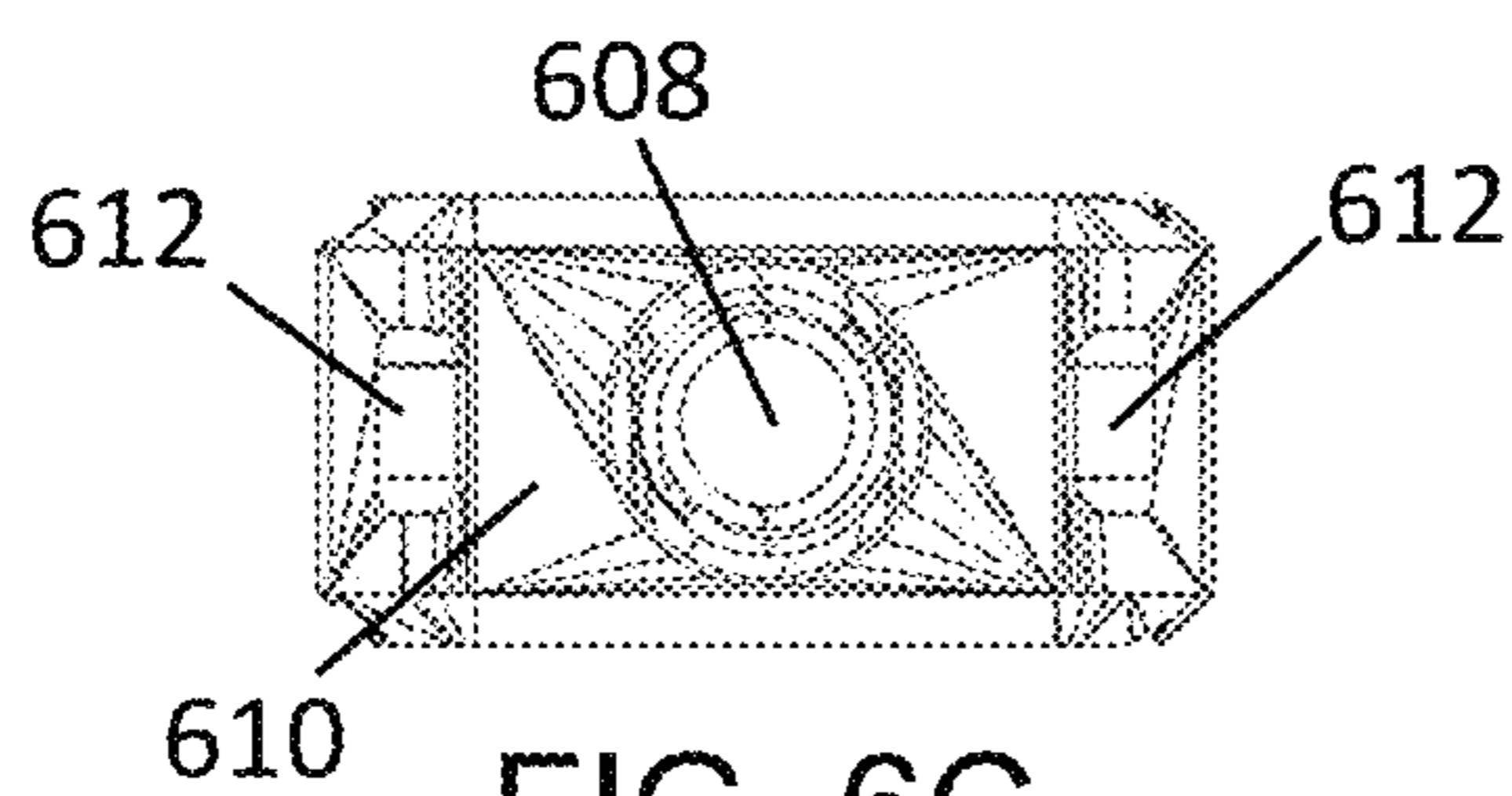


FIG. 6C

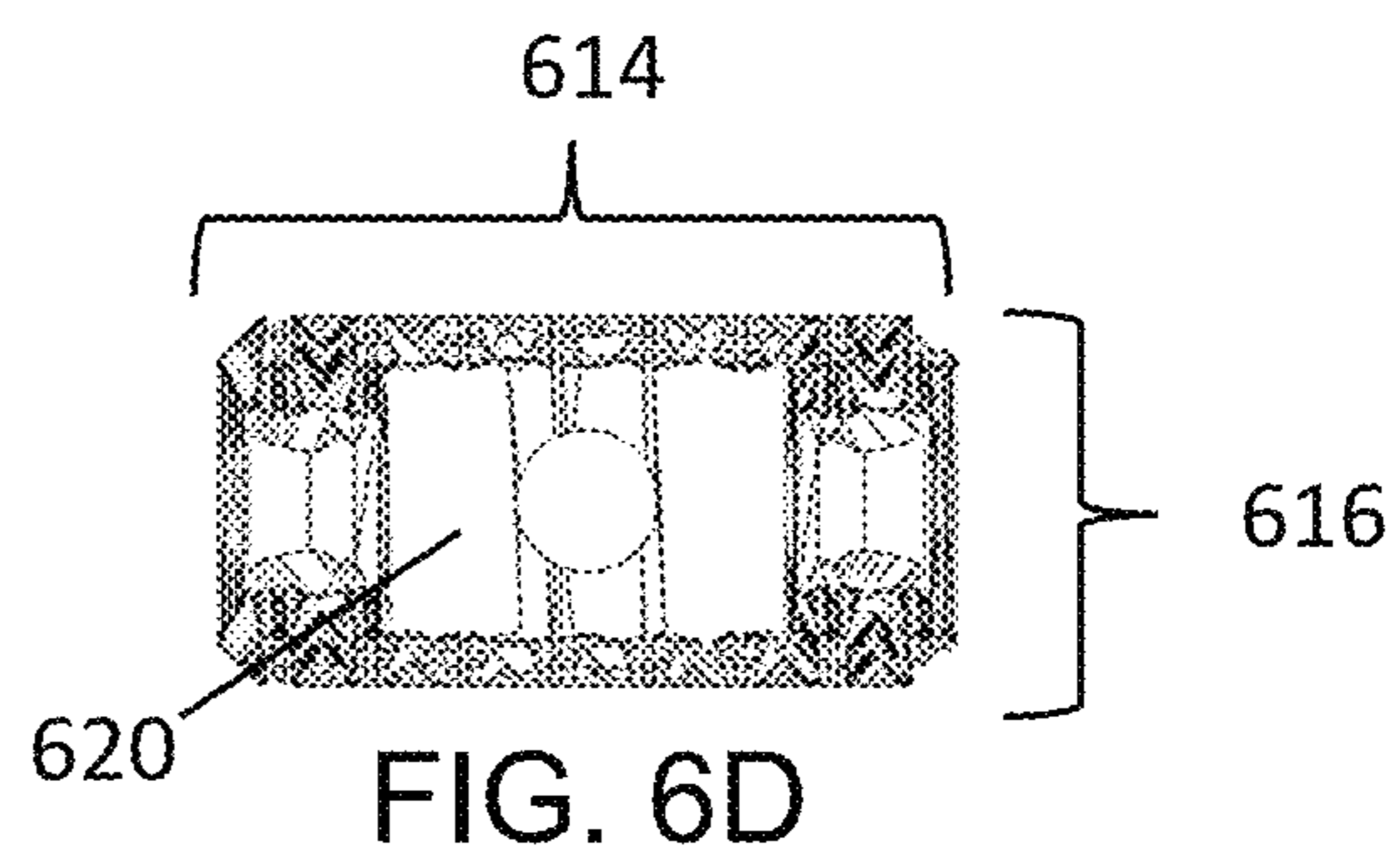


FIG. 6D

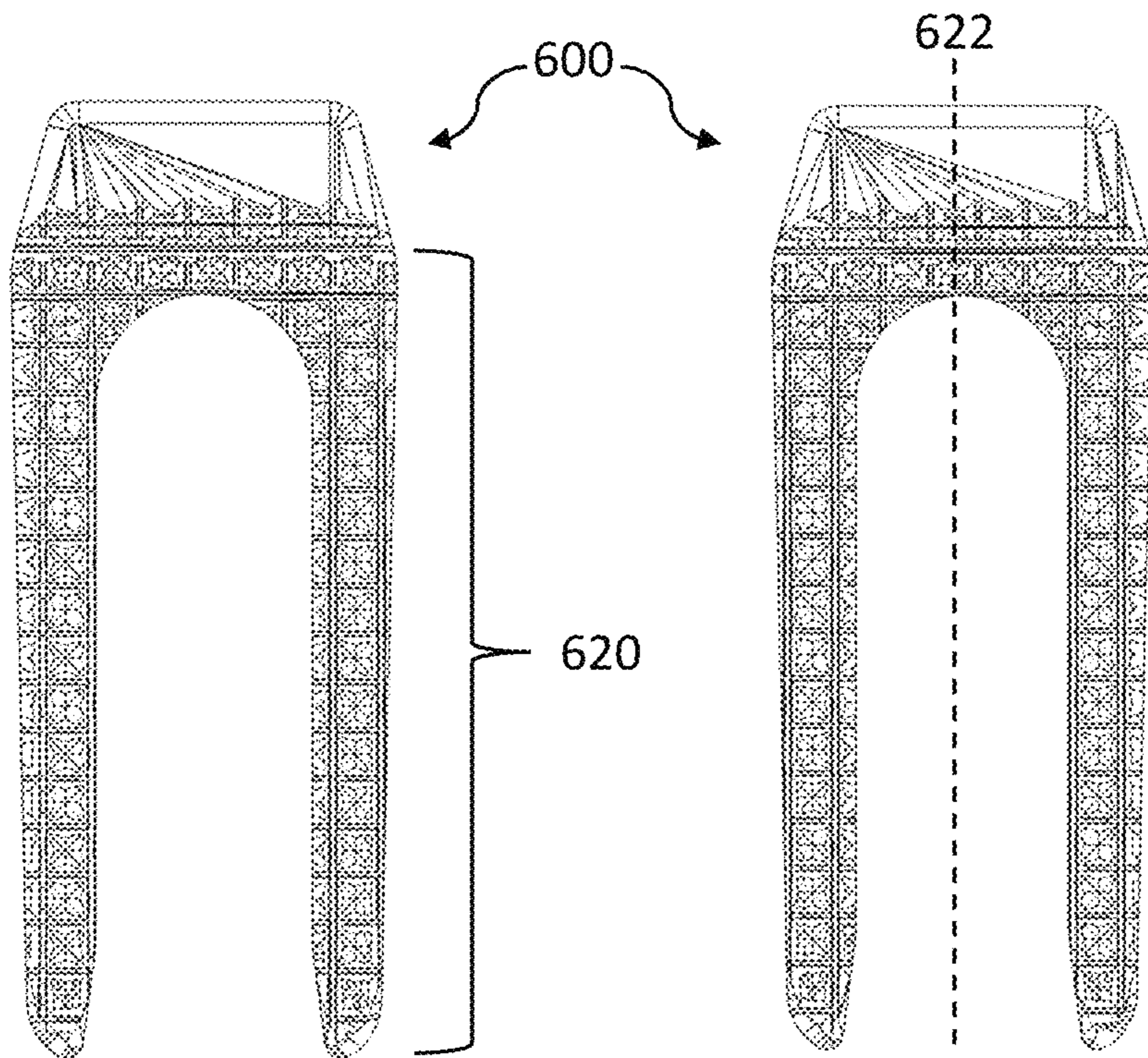


FIG. 6E

FIG. 6F

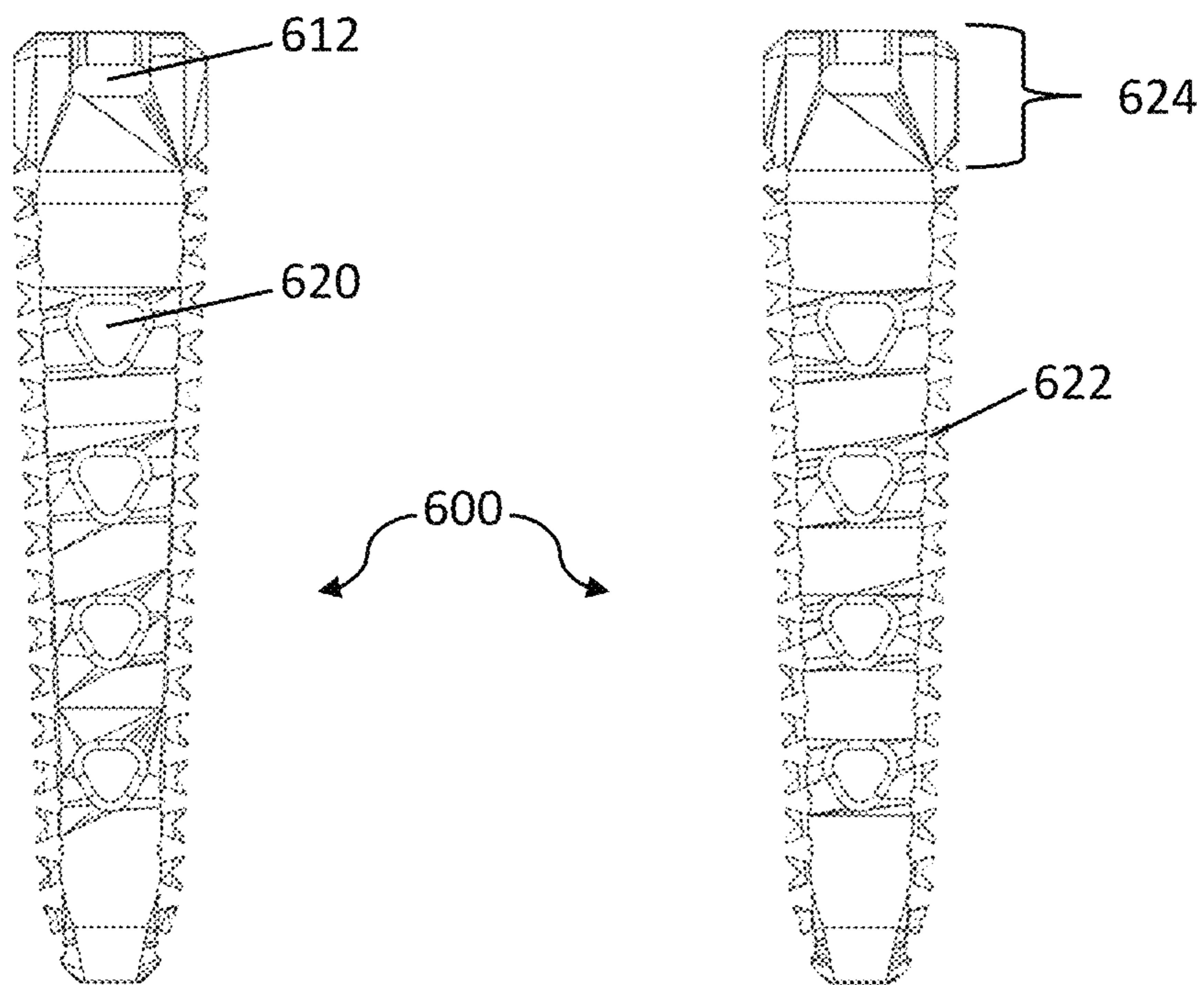


FIG. 6G

FIG. 6H

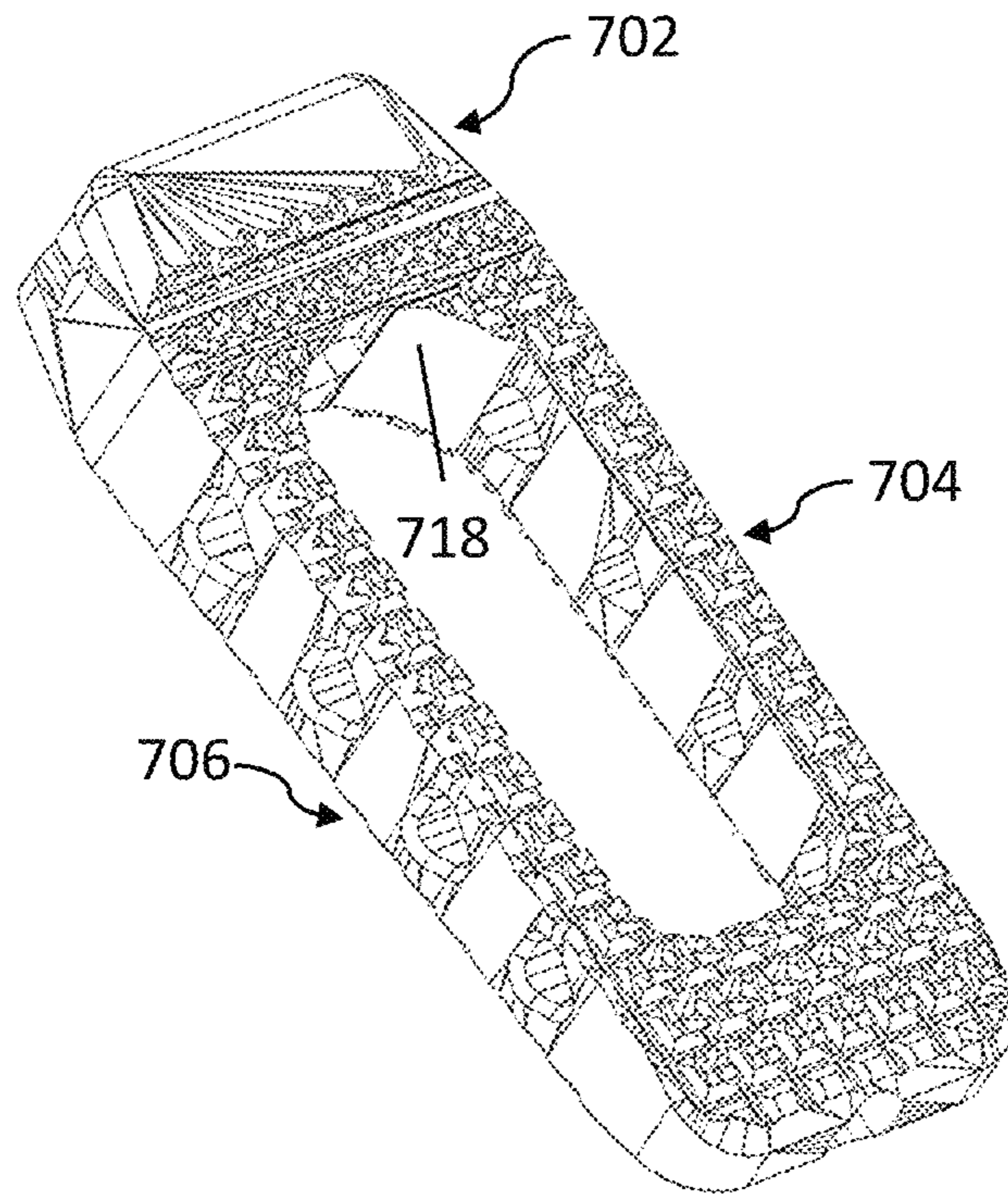


FIG. 7A

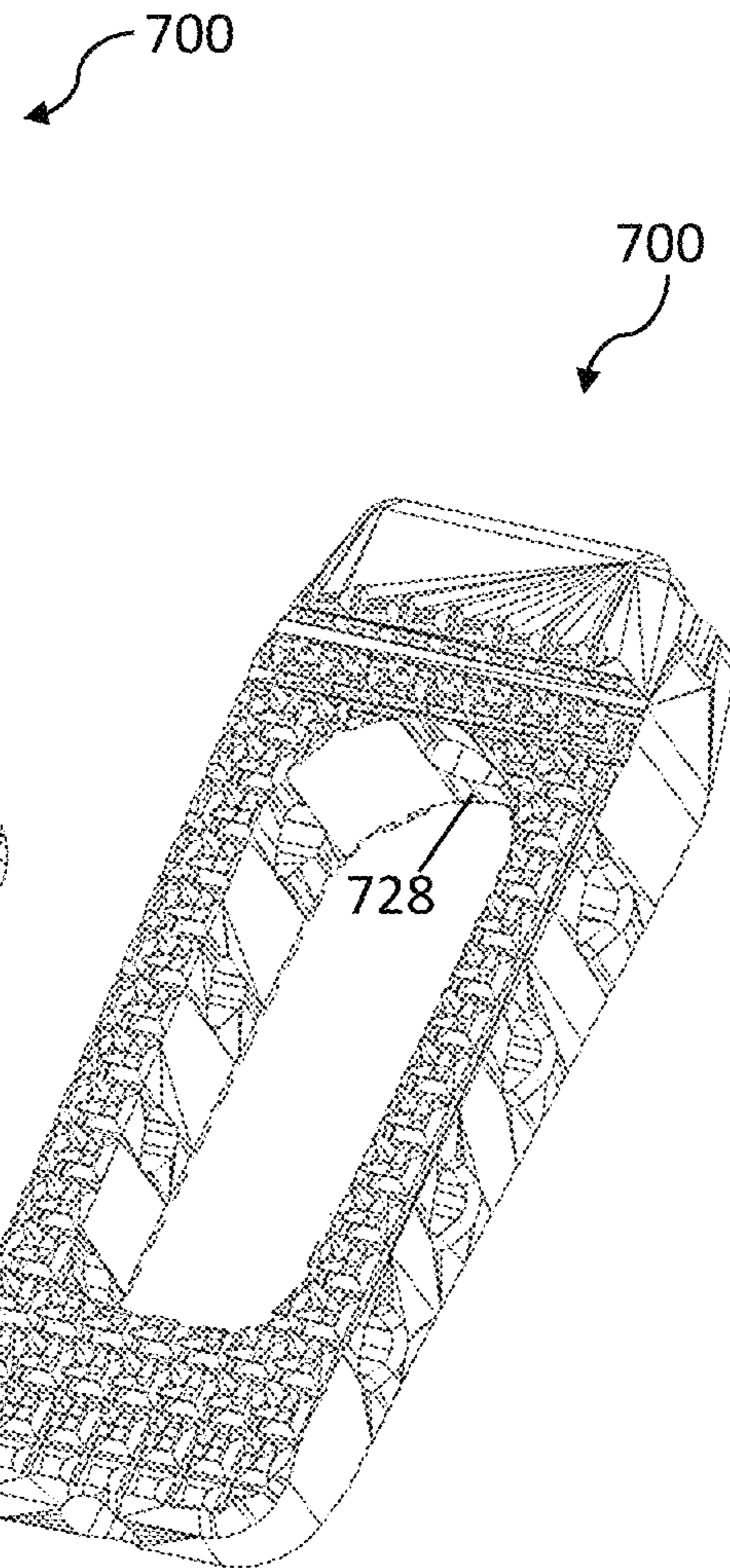


FIG. 7B

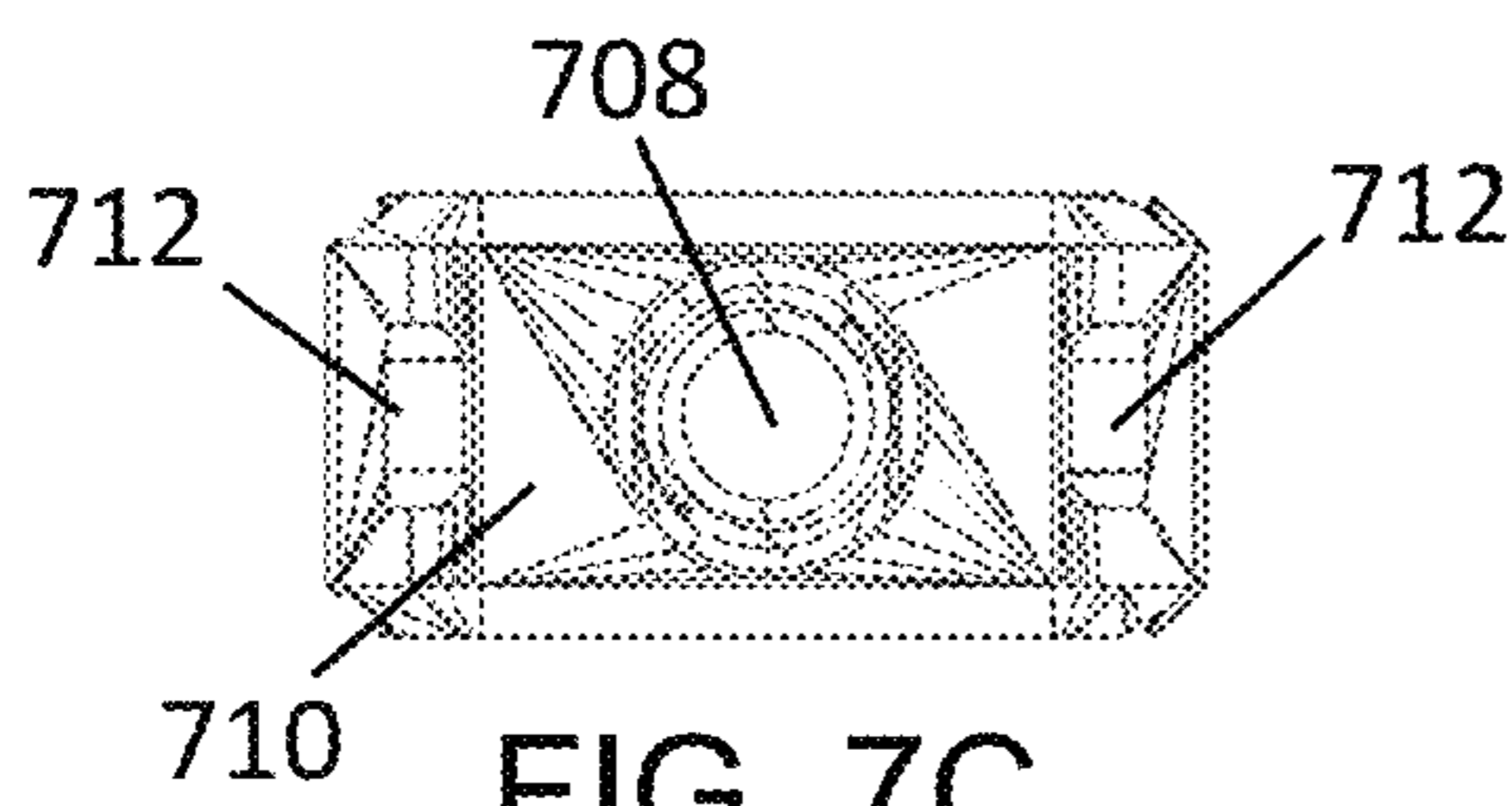


FIG. 7C

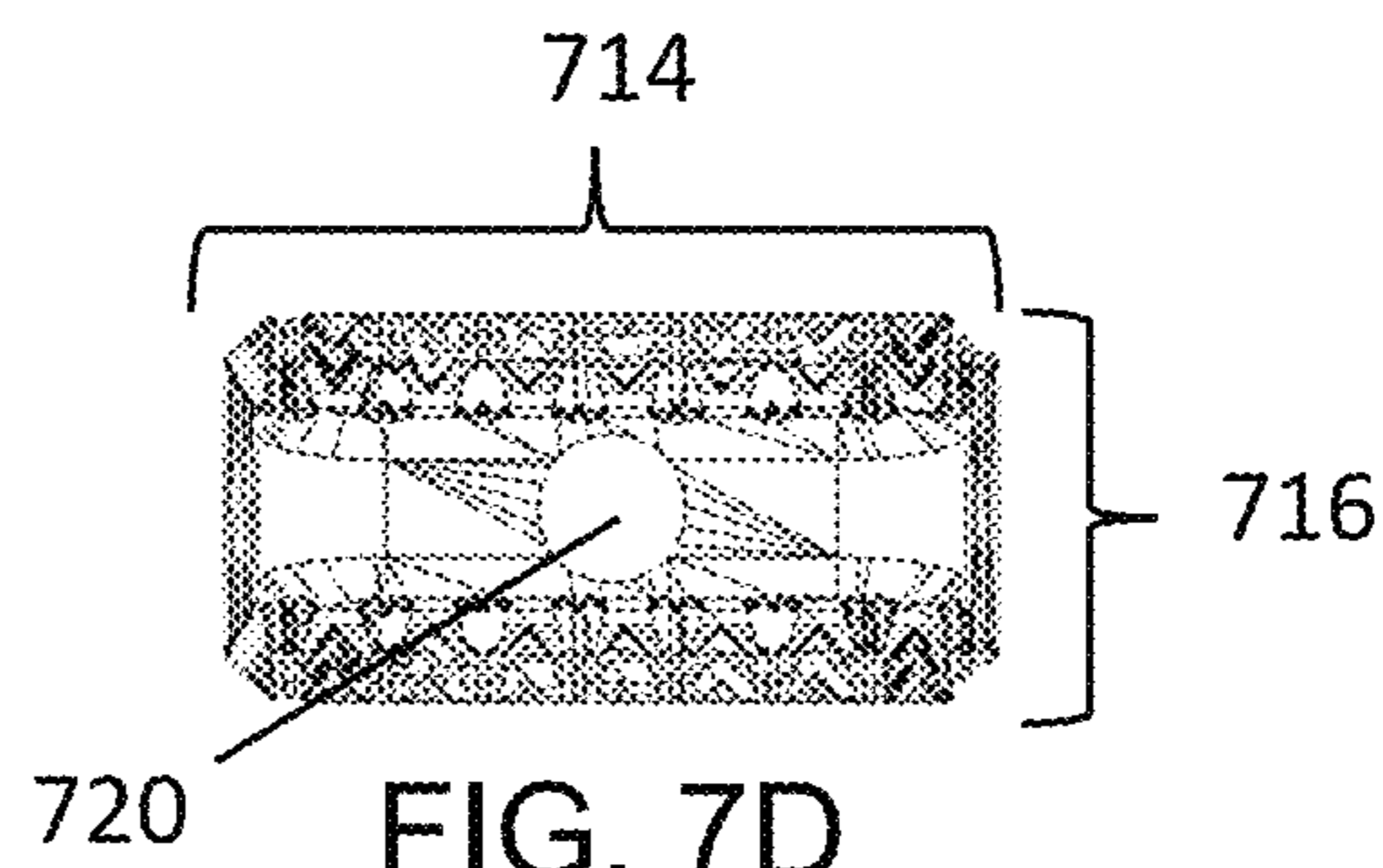


FIG. 7D

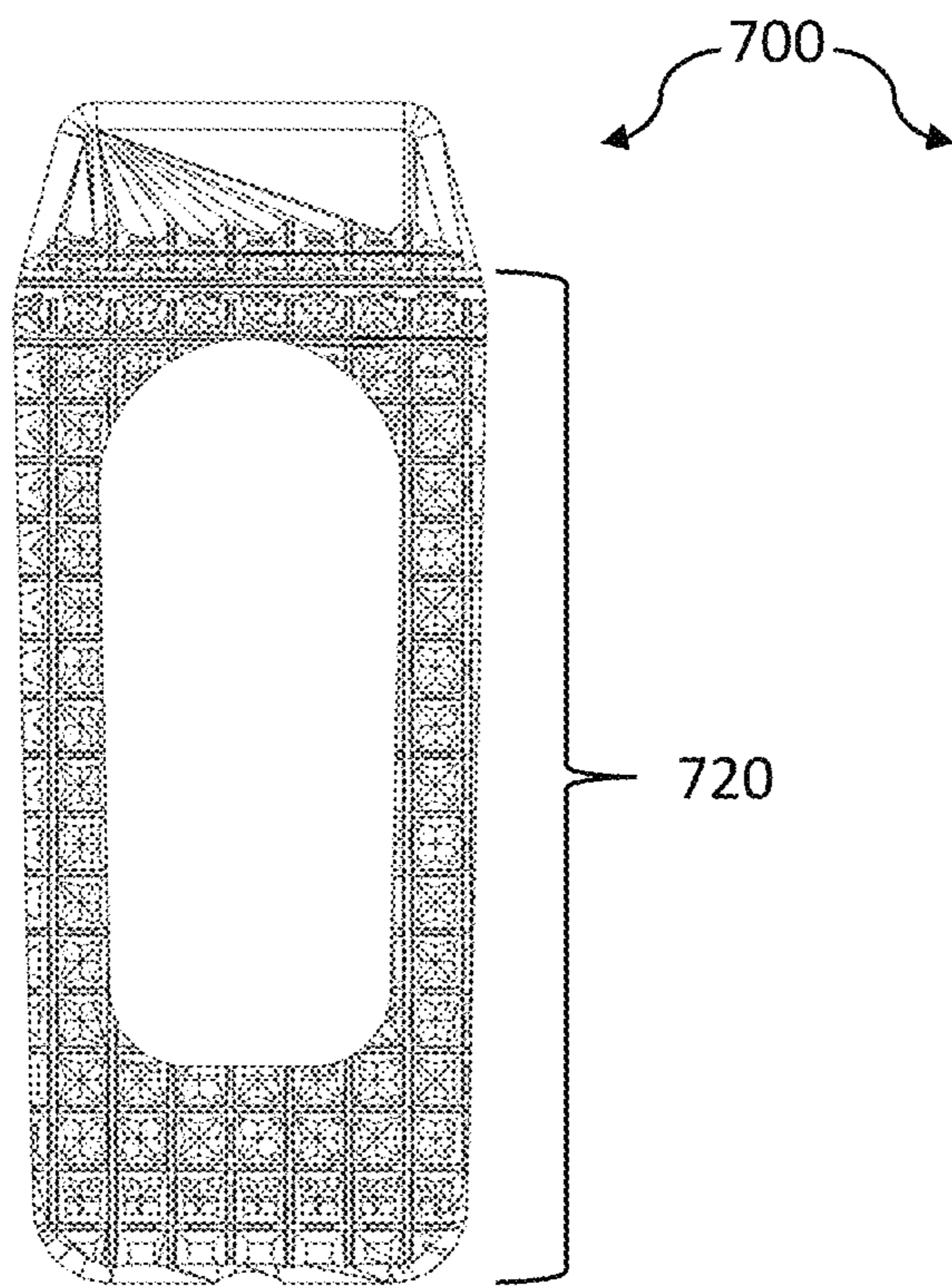


FIG. 7E

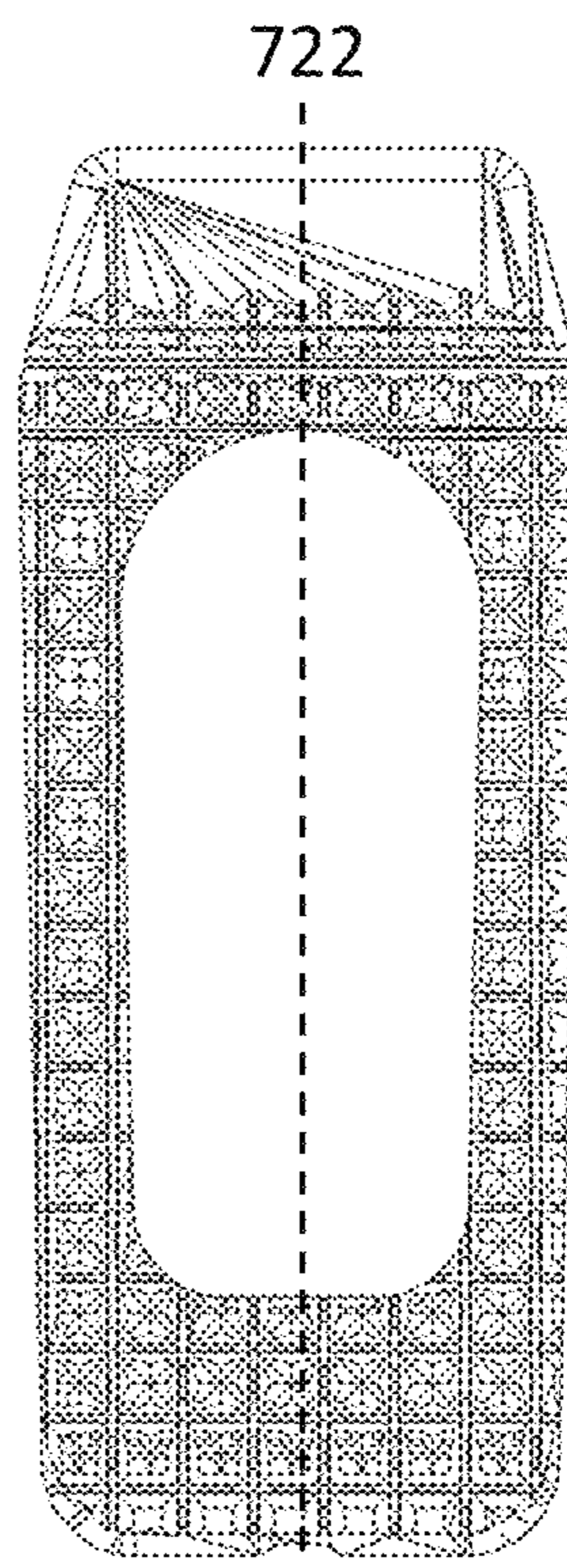


FIG. 7F

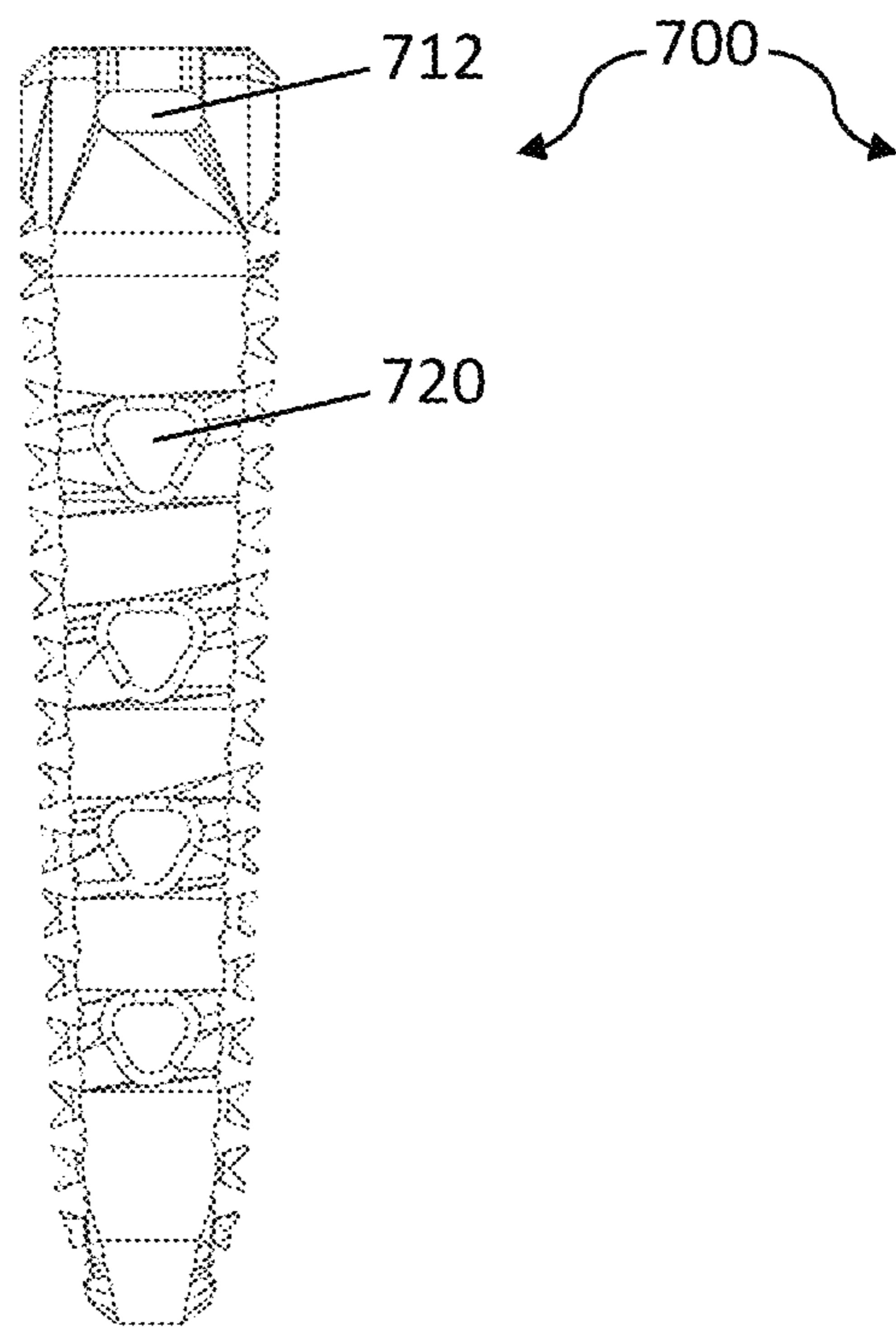


FIG. 7G

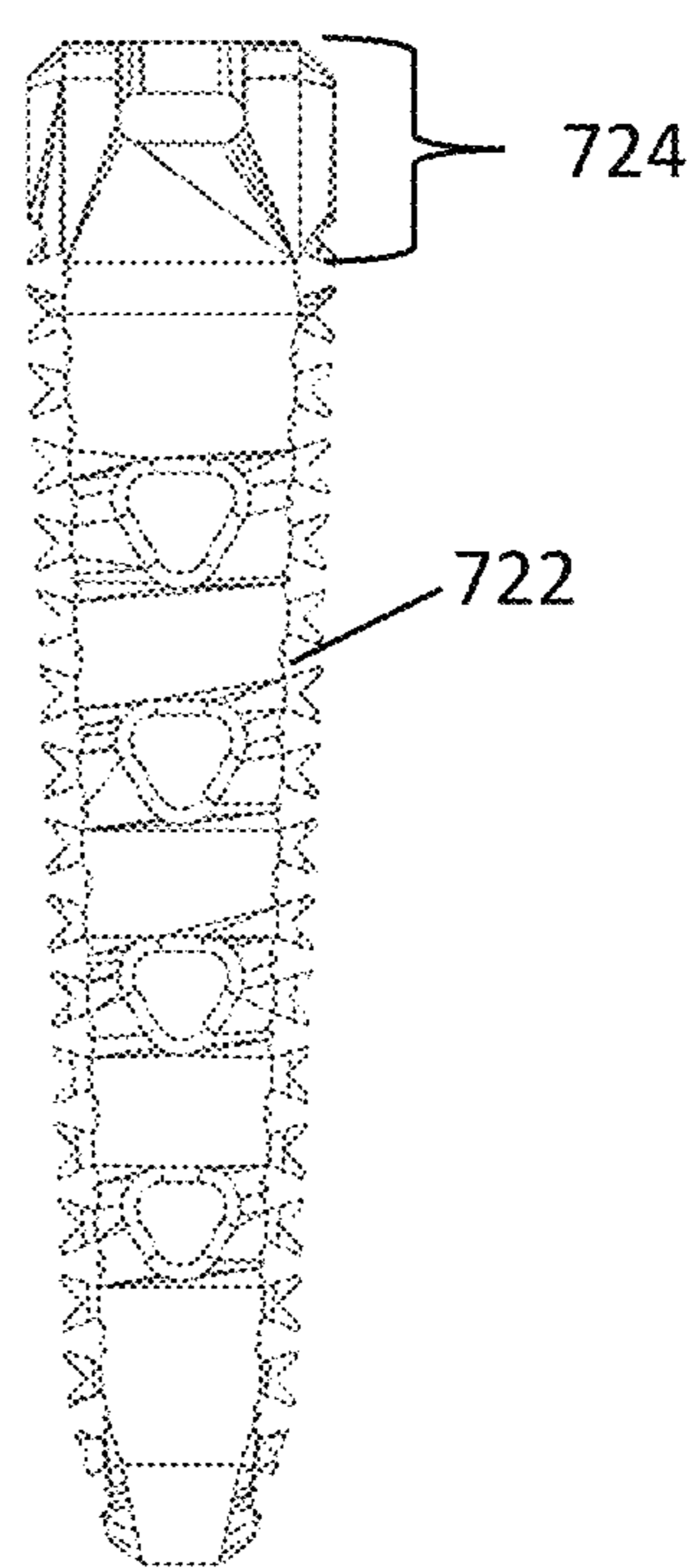


FIG. 7H

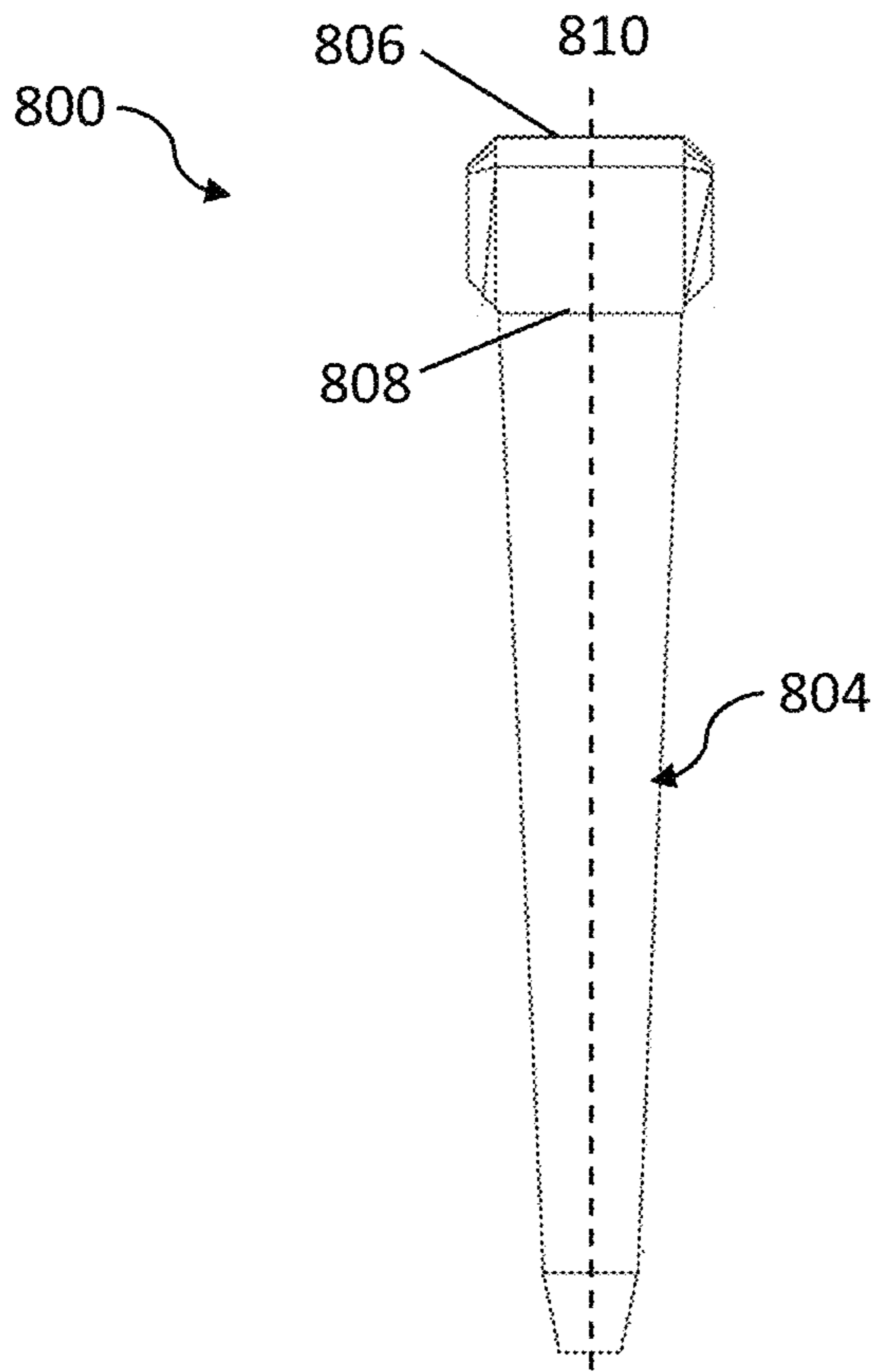


FIG. 8

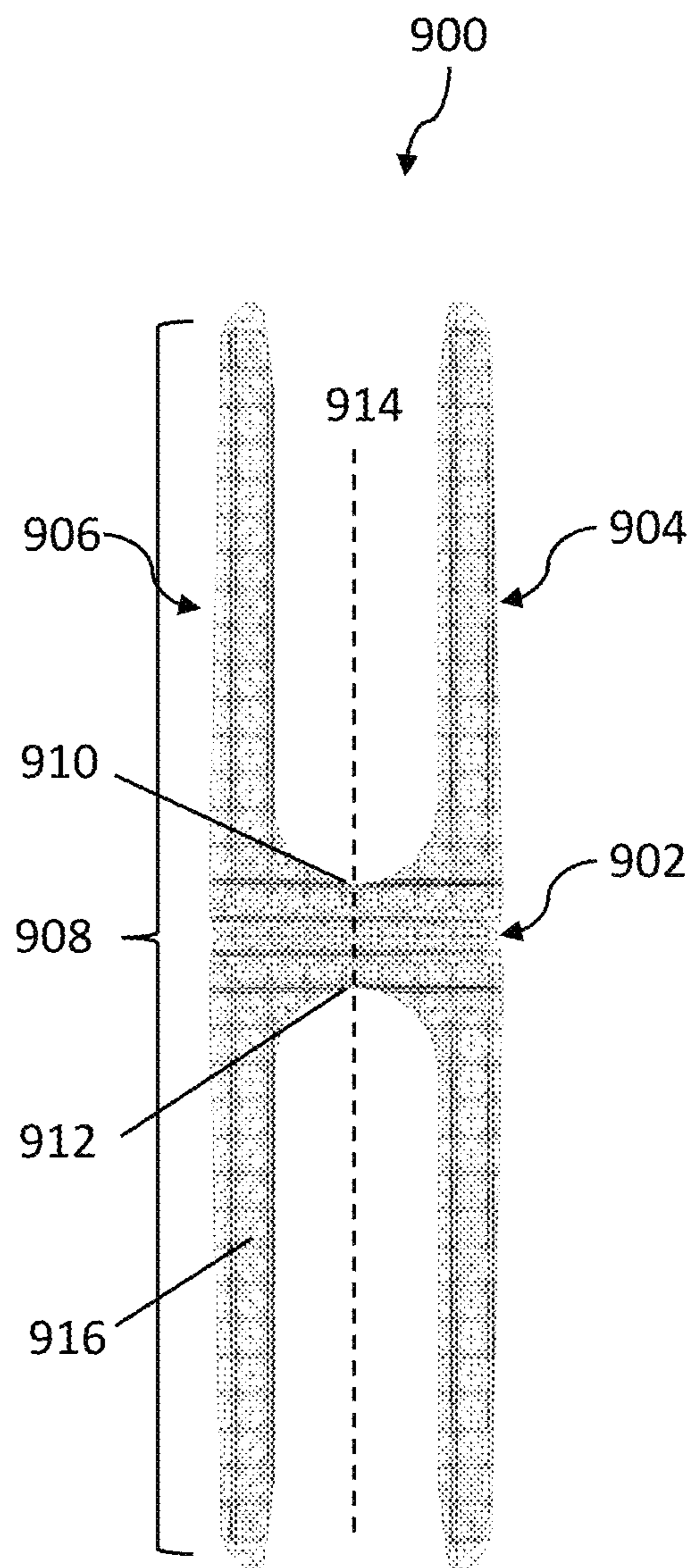
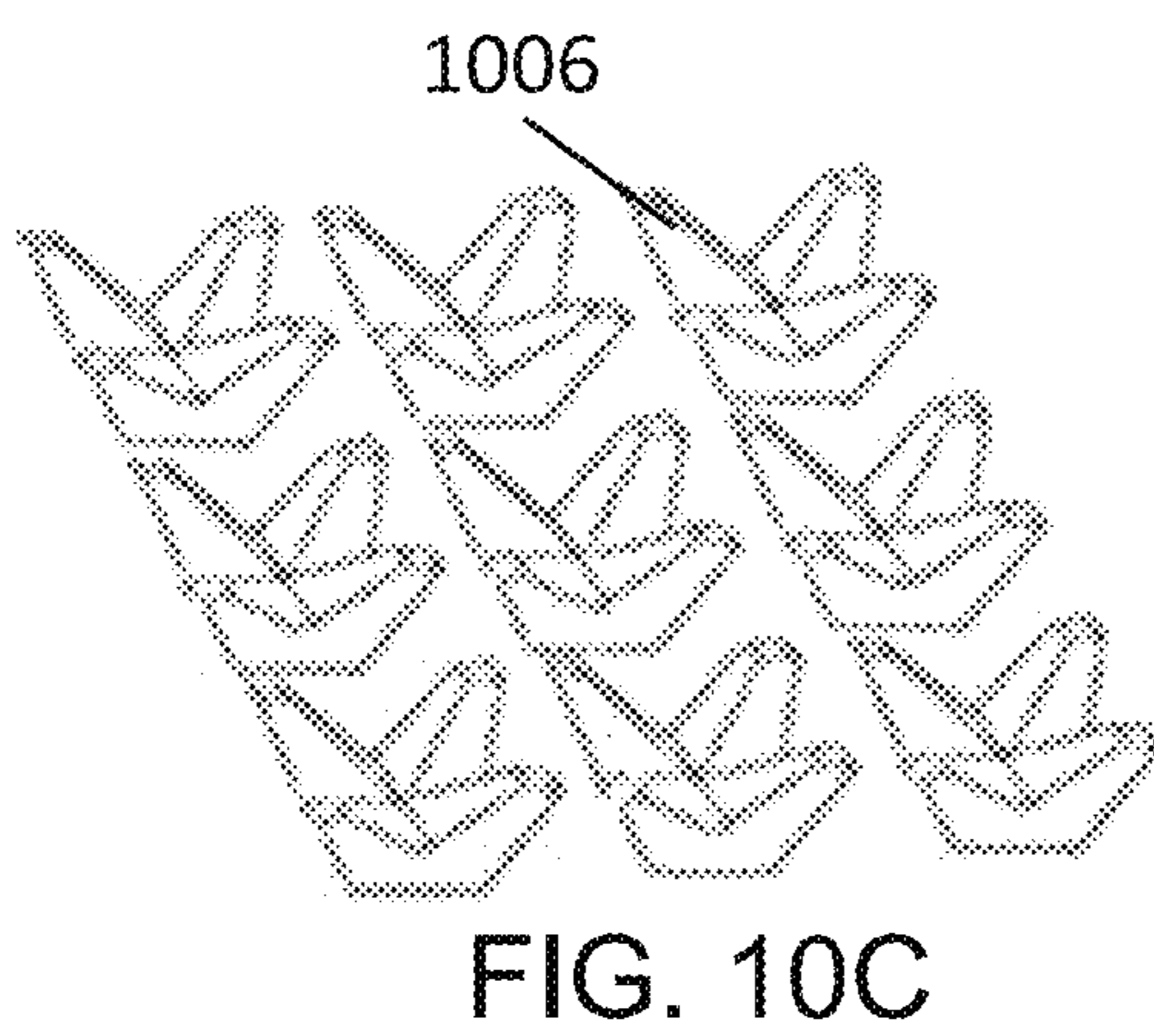
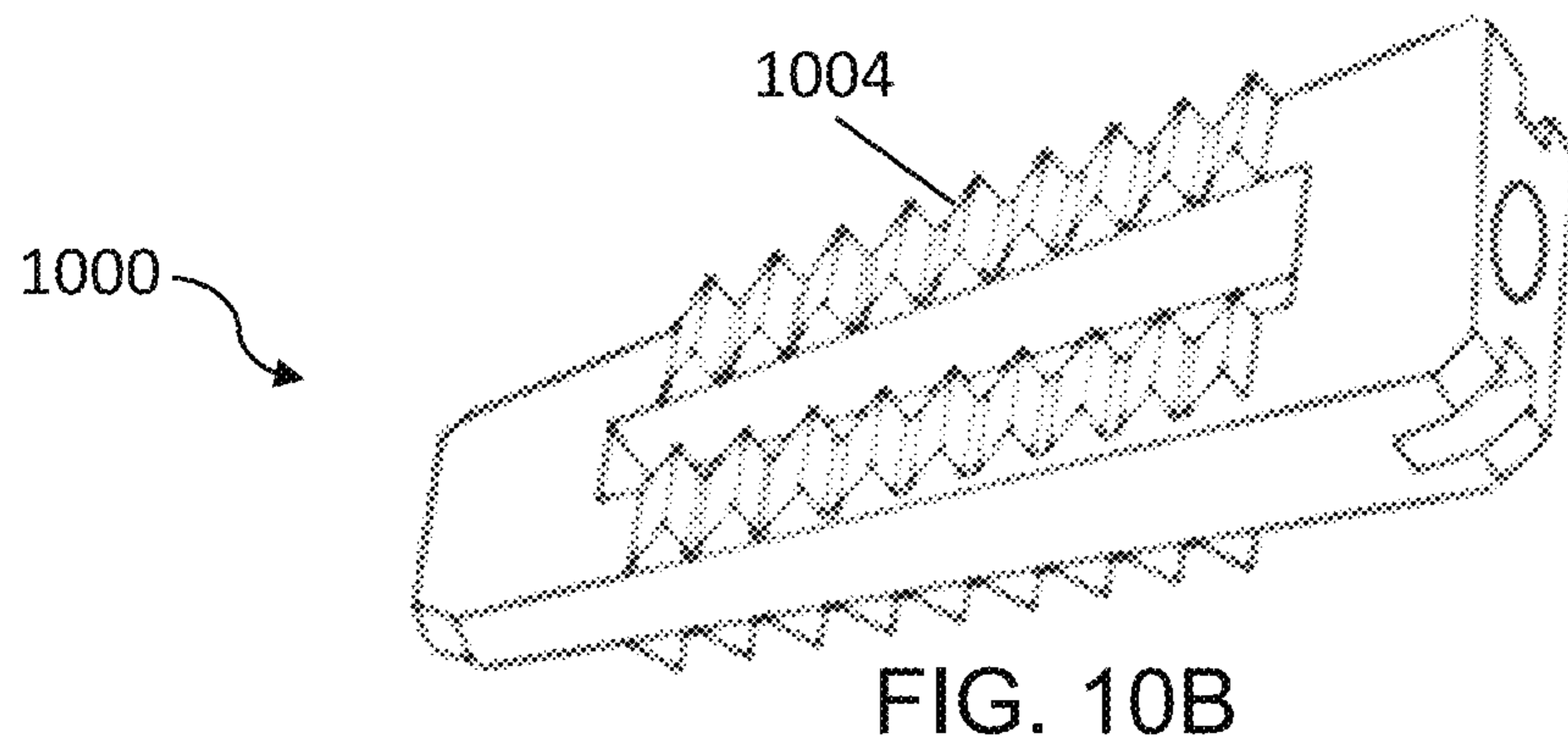
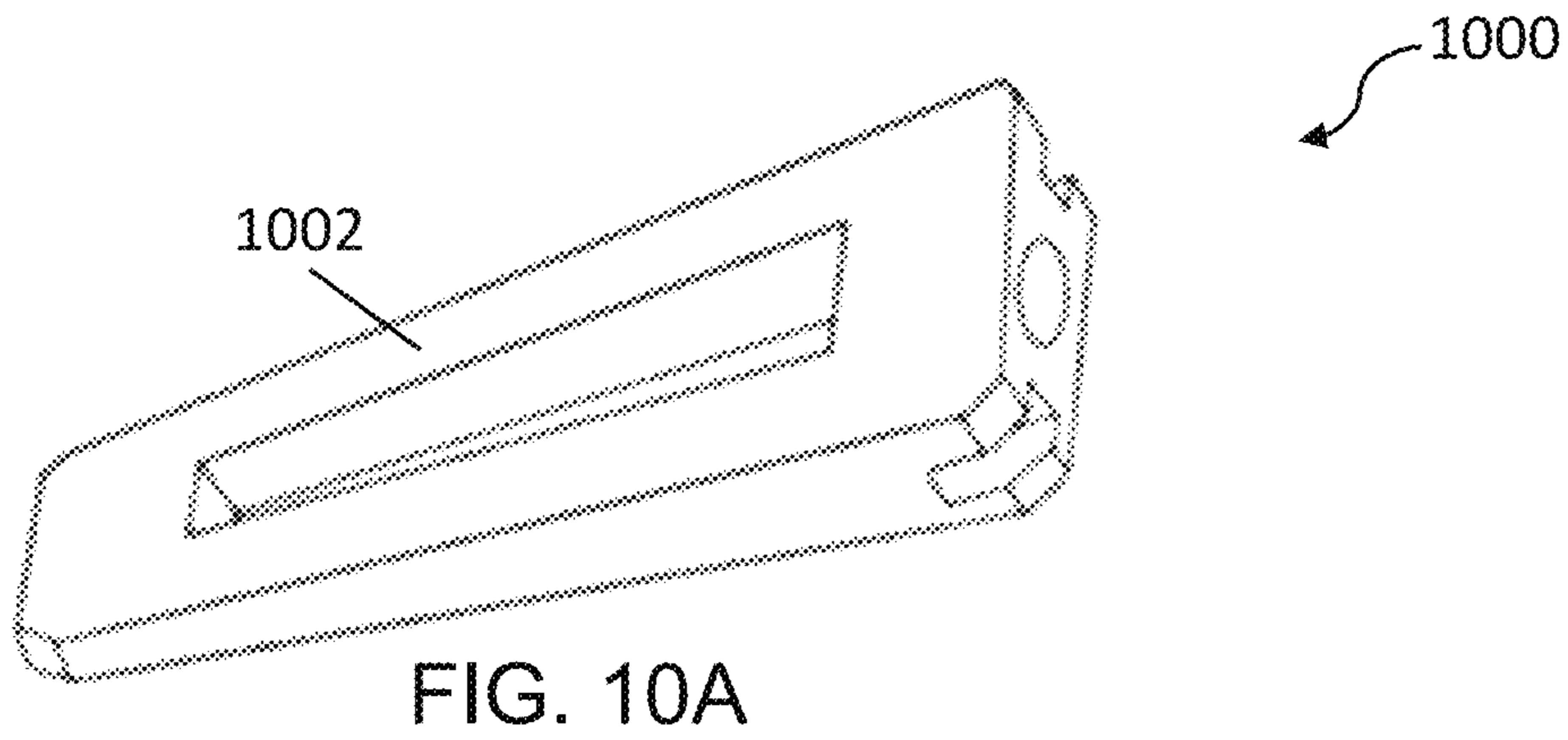


FIG. 9



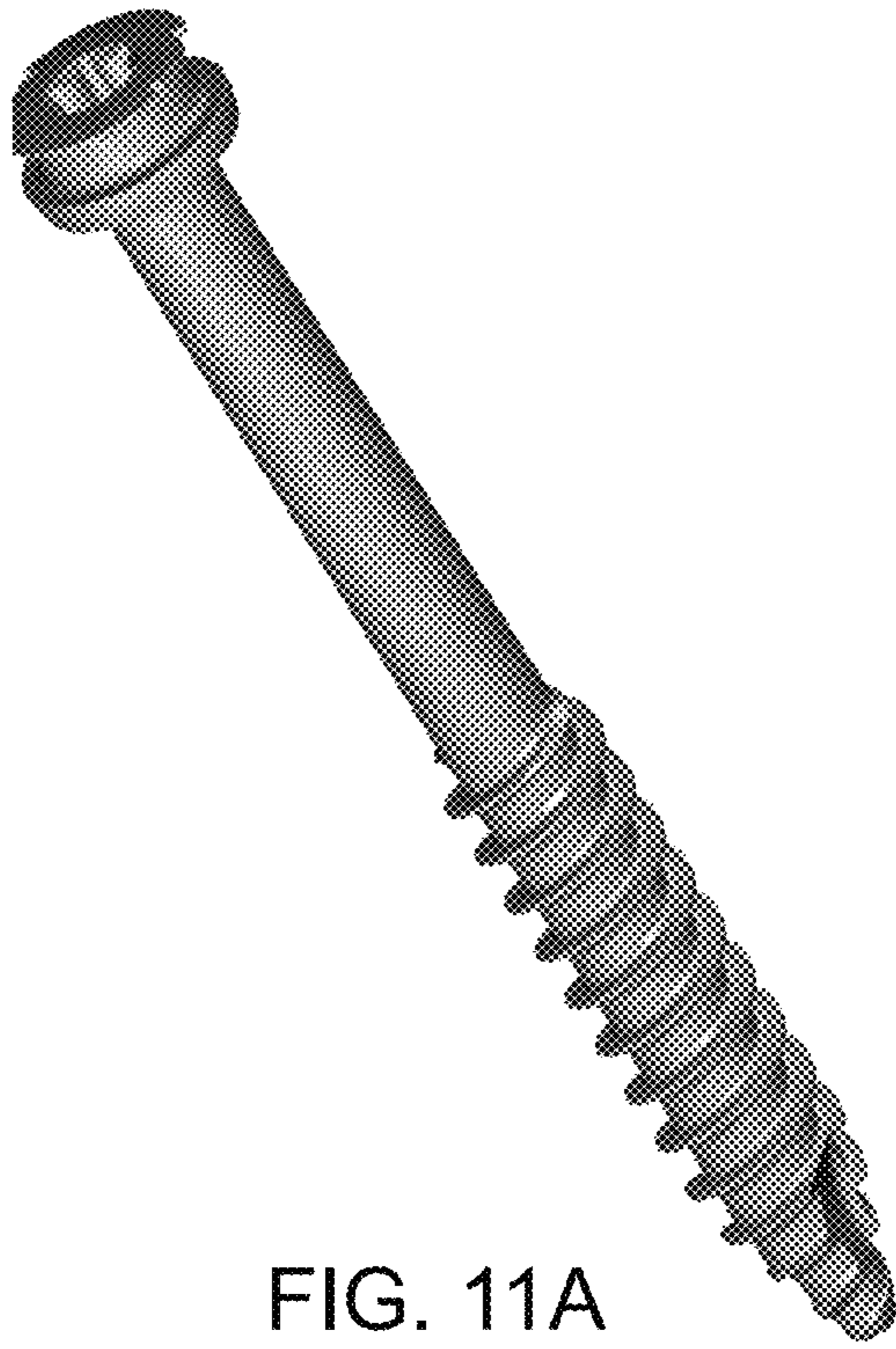


FIG. 11A

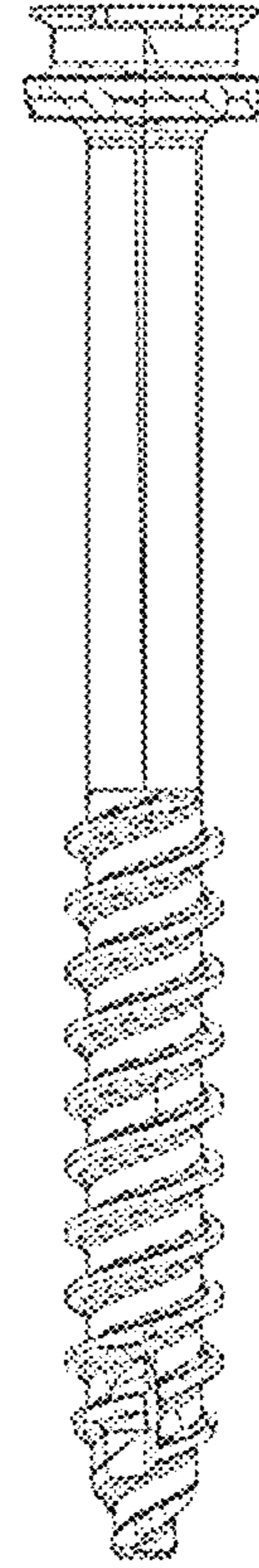


FIG. 11B

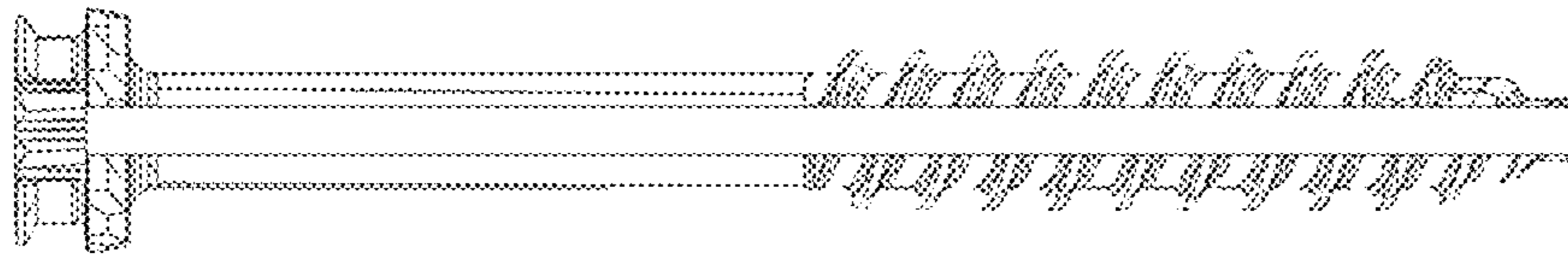


FIG. 11C

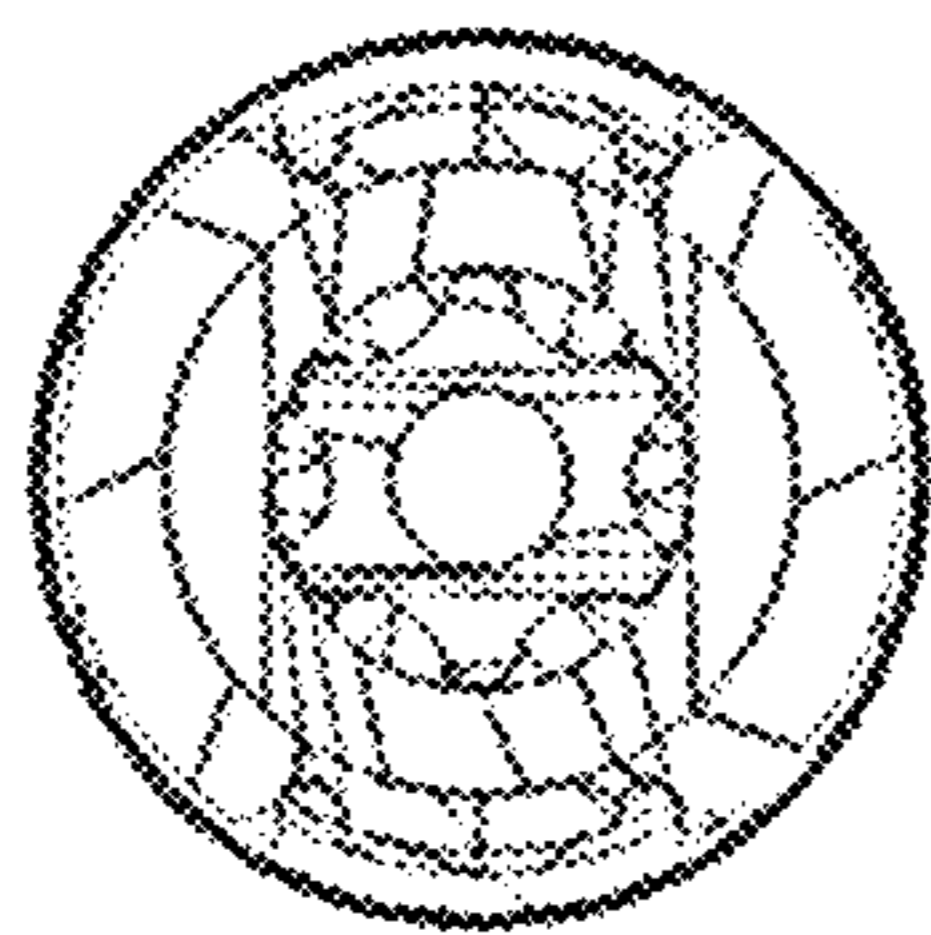


FIG. 11D

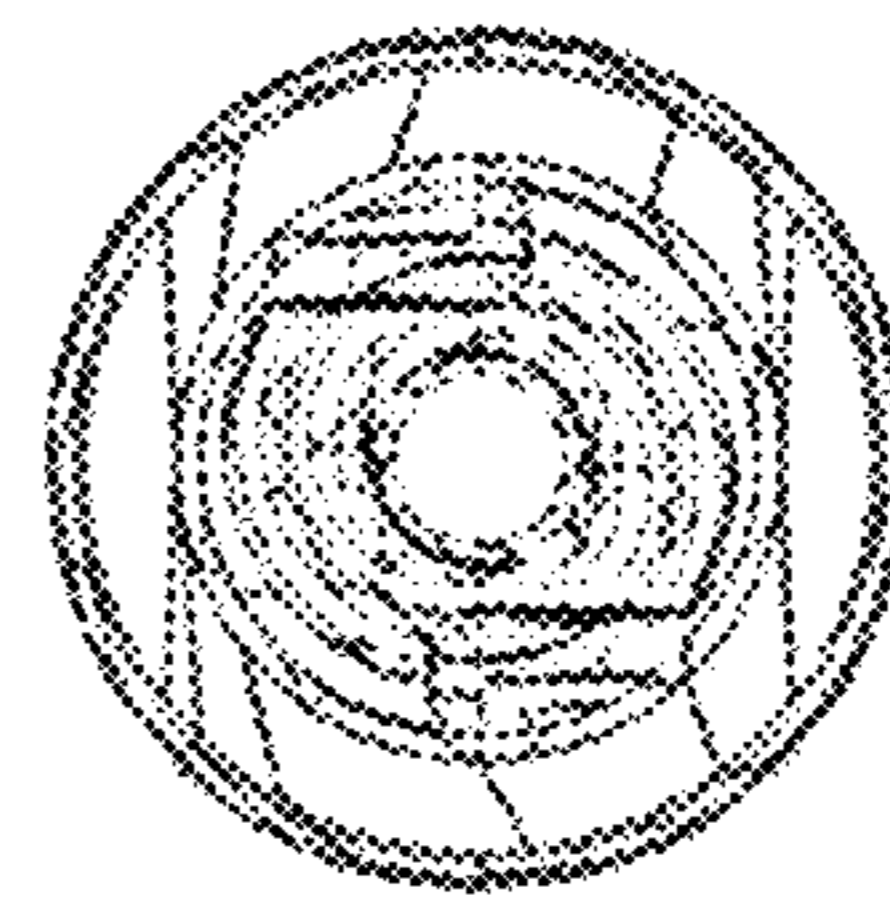


FIG. 11E

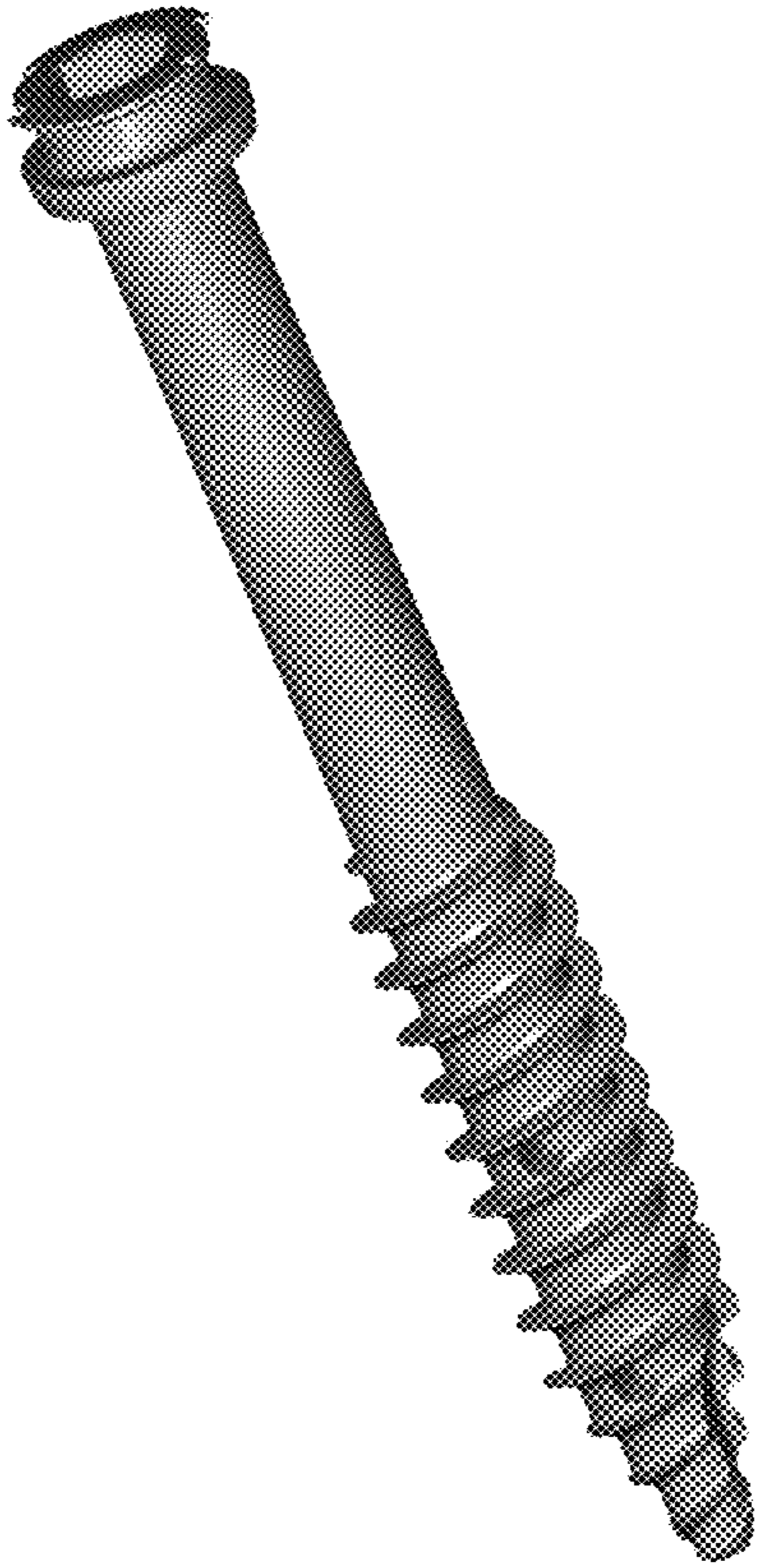


FIG. 12A

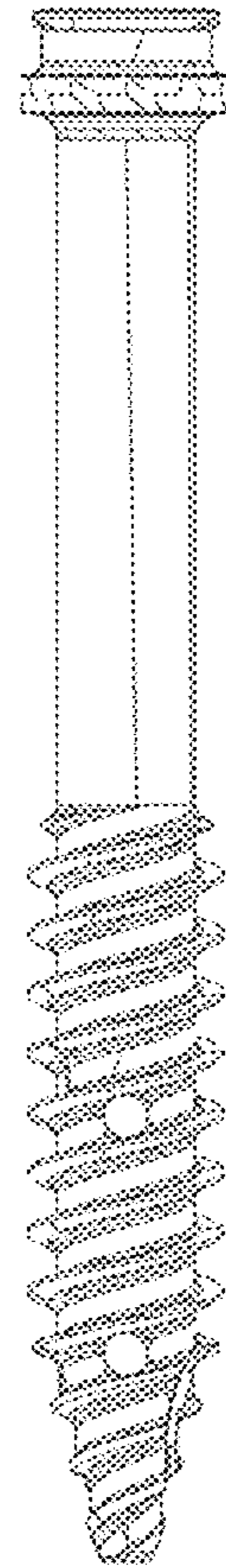


FIG. 12B

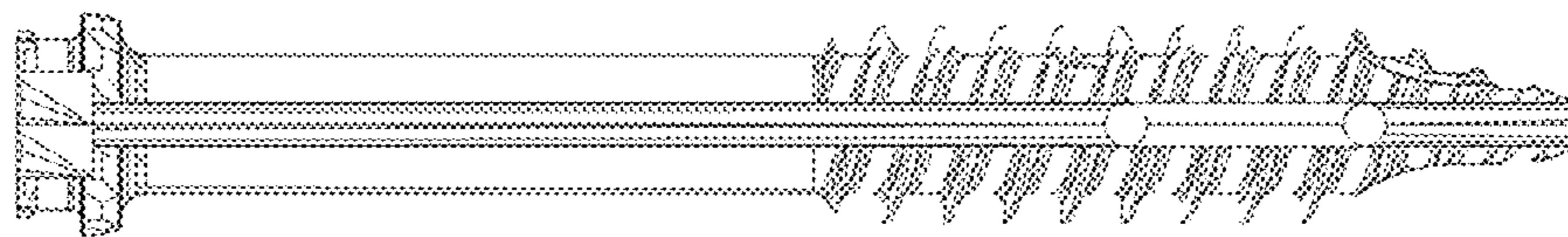


FIG. 12C

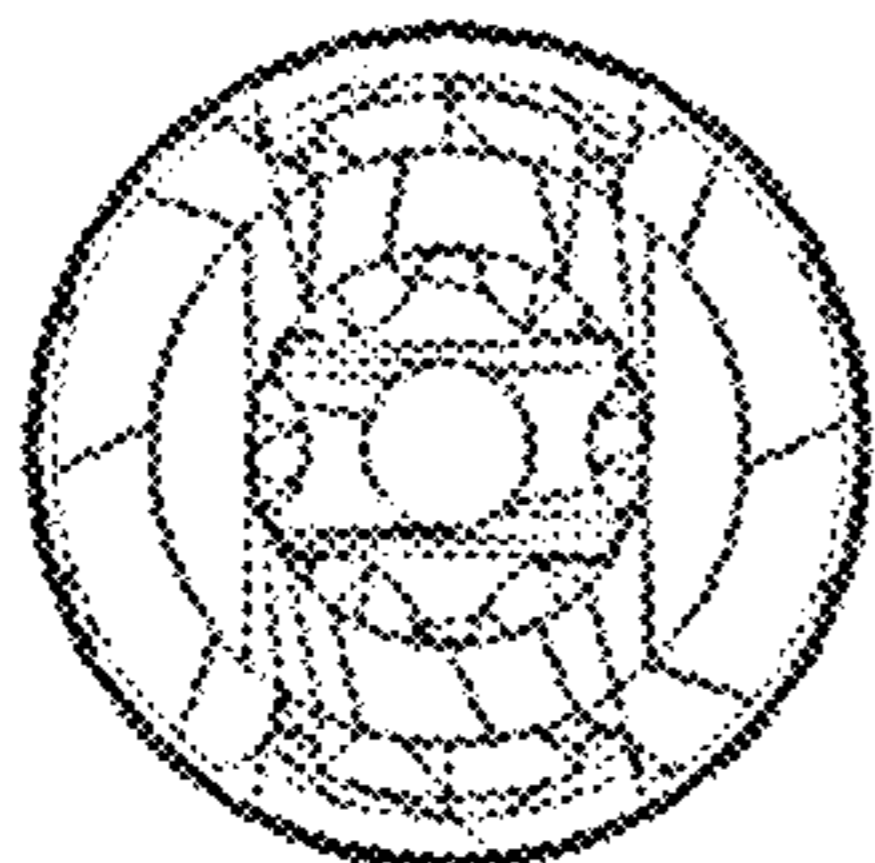


FIG. 12D

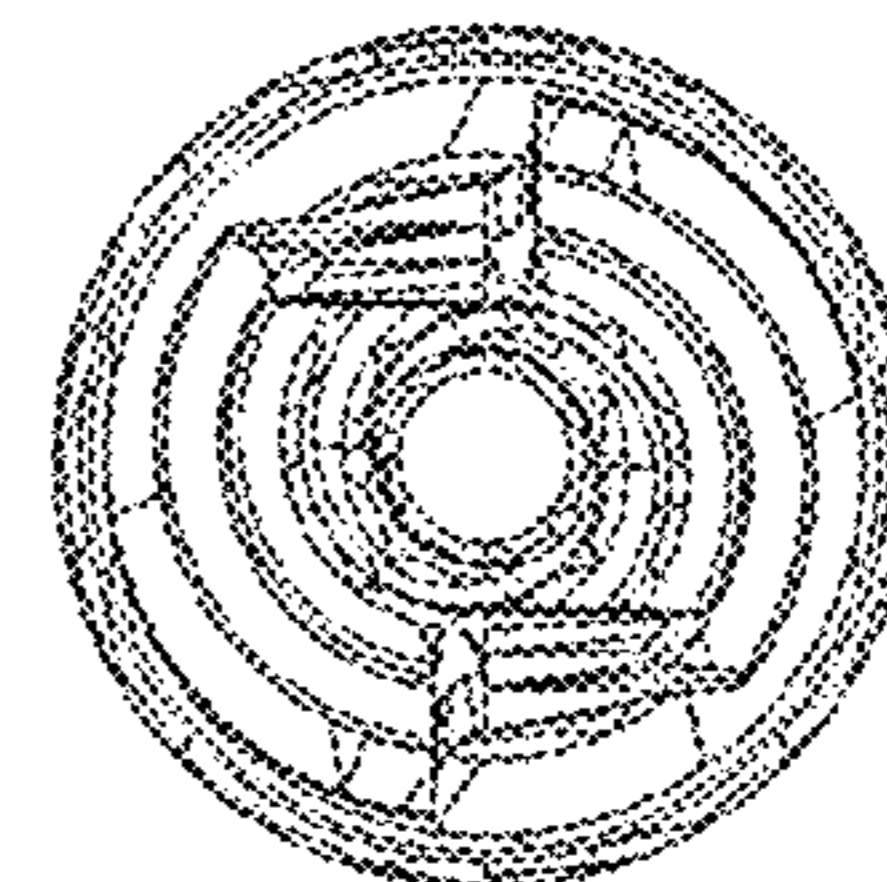


FIG. 12E

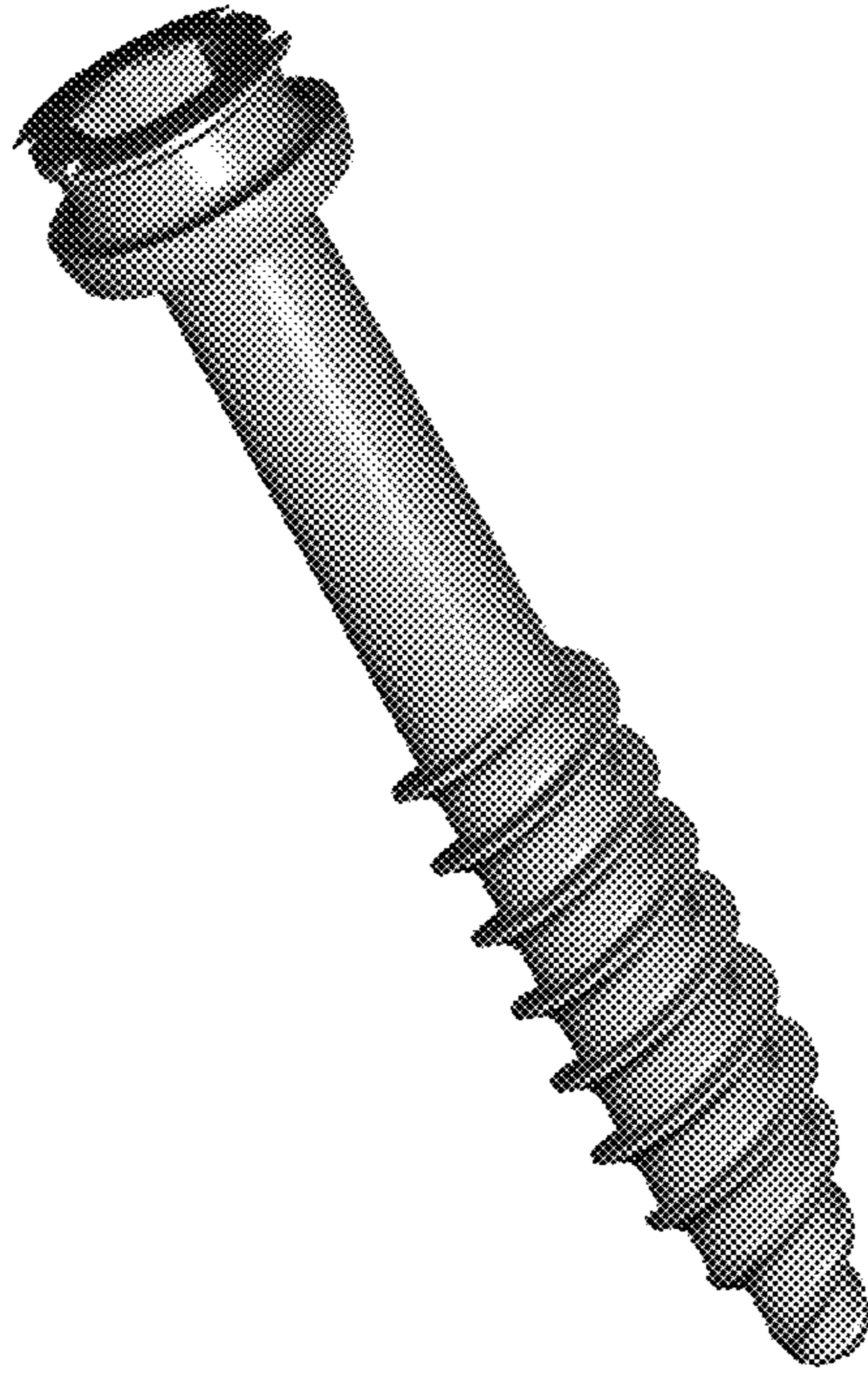


FIG. 13A

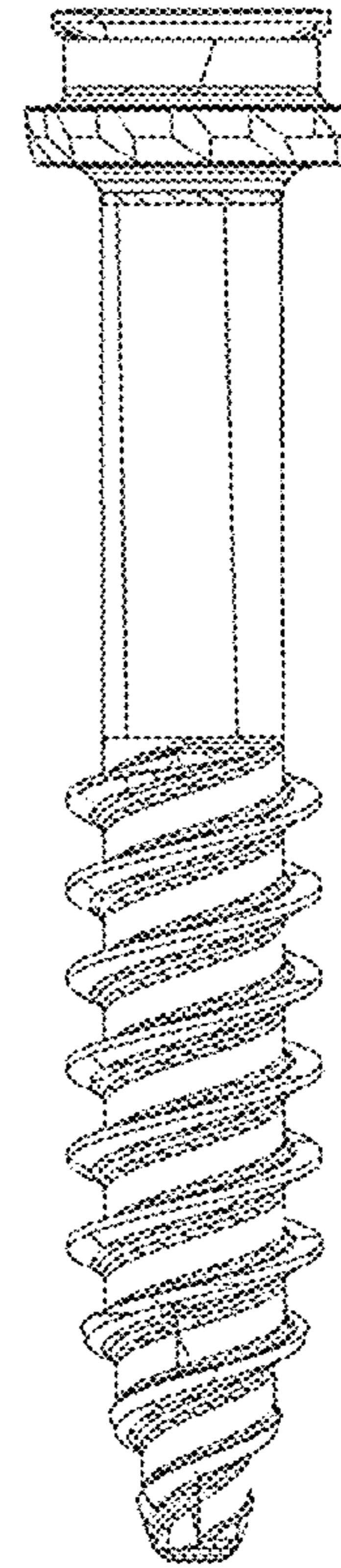


FIG. 13B



FIG. 13C

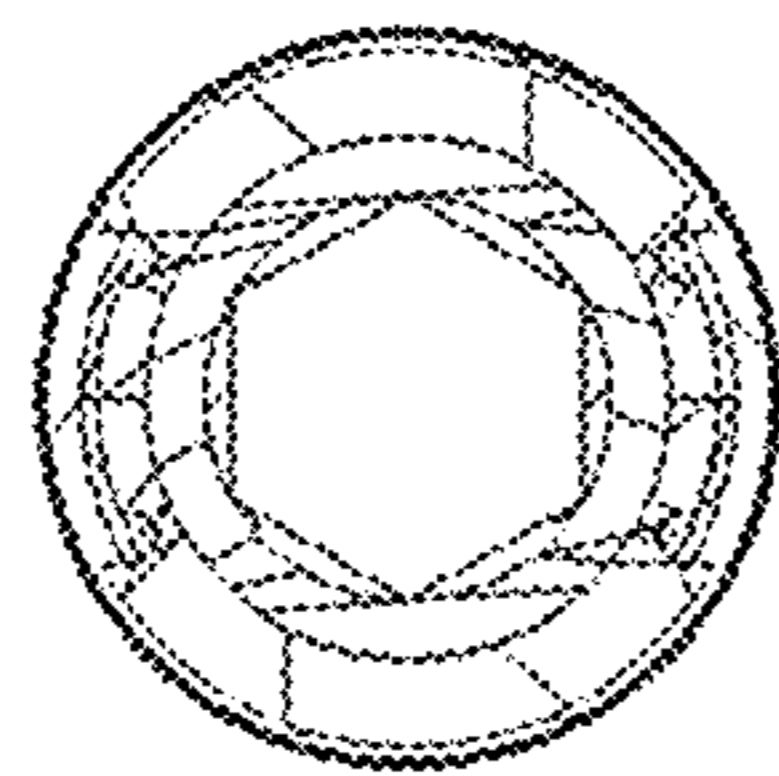


FIG. 13D

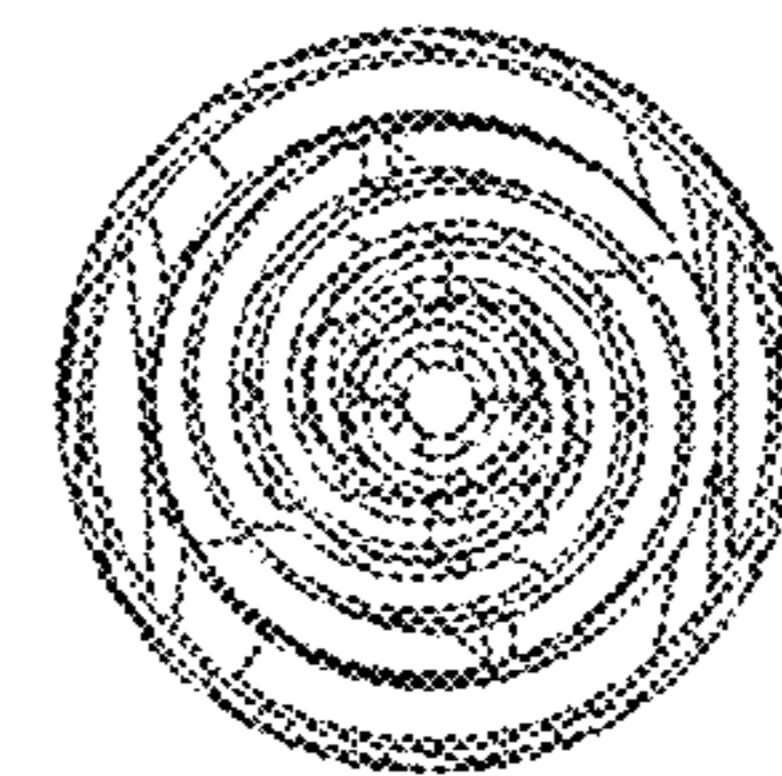


FIG. 13E

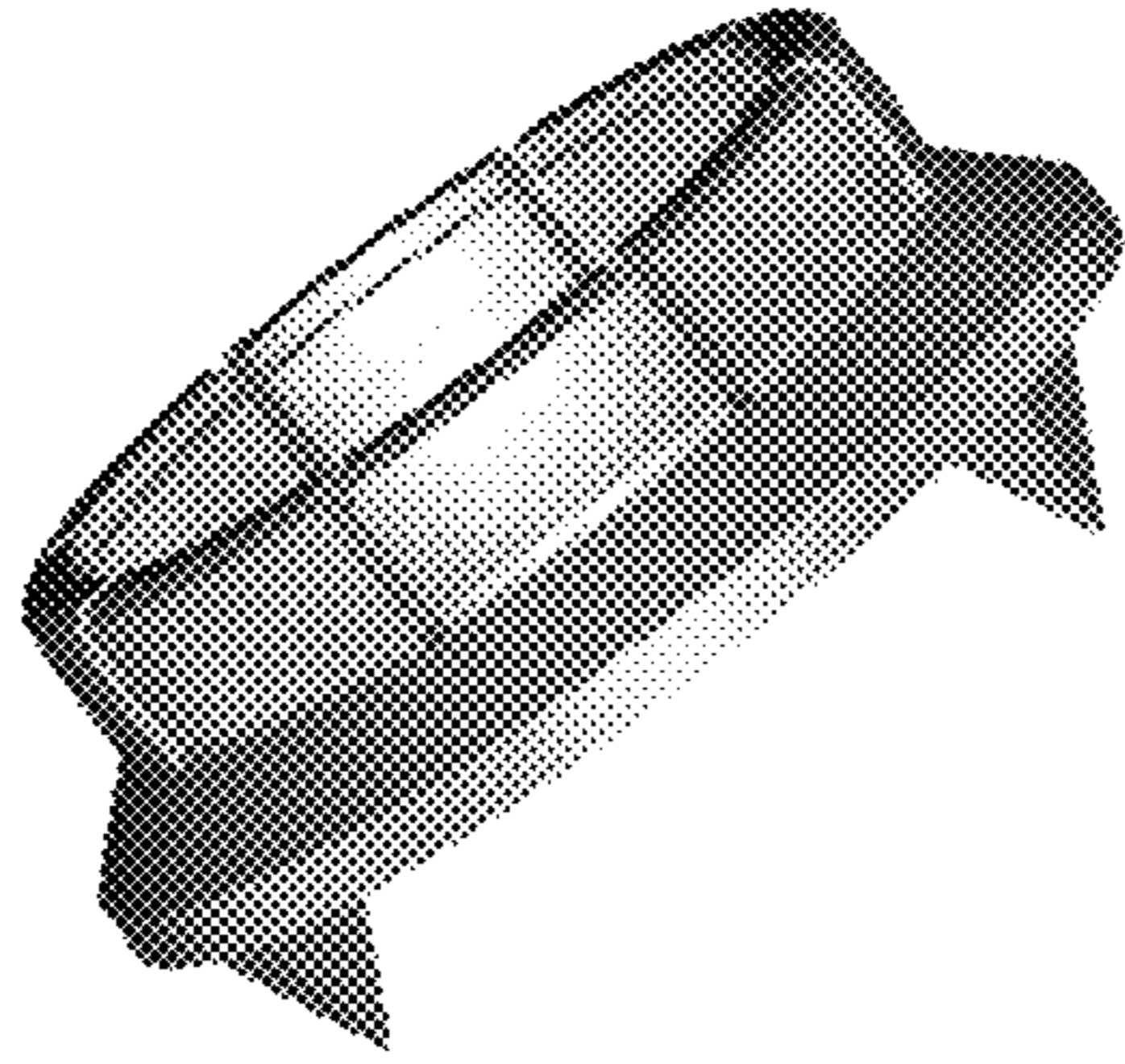


FIG. 14A

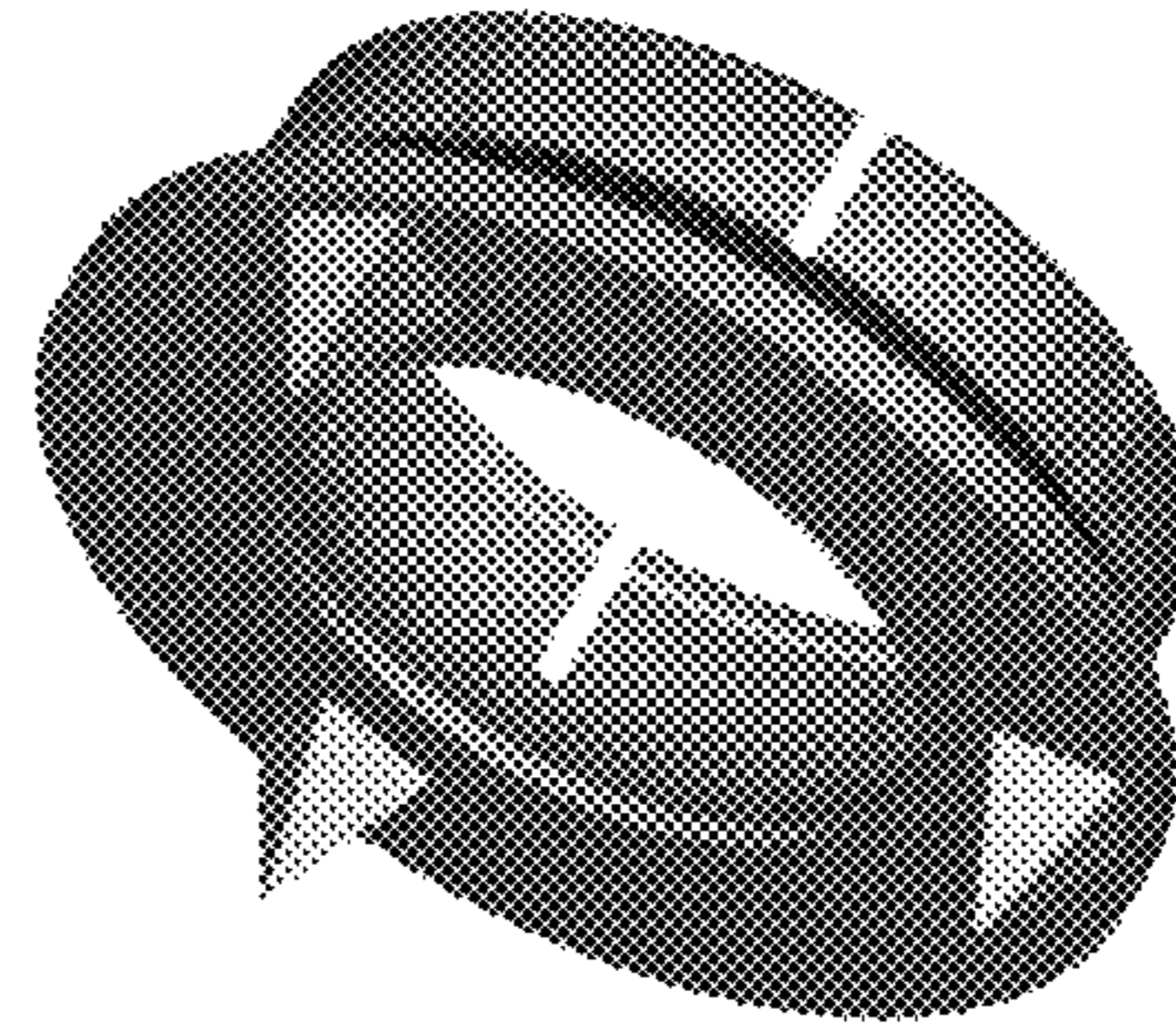


FIG. 14B

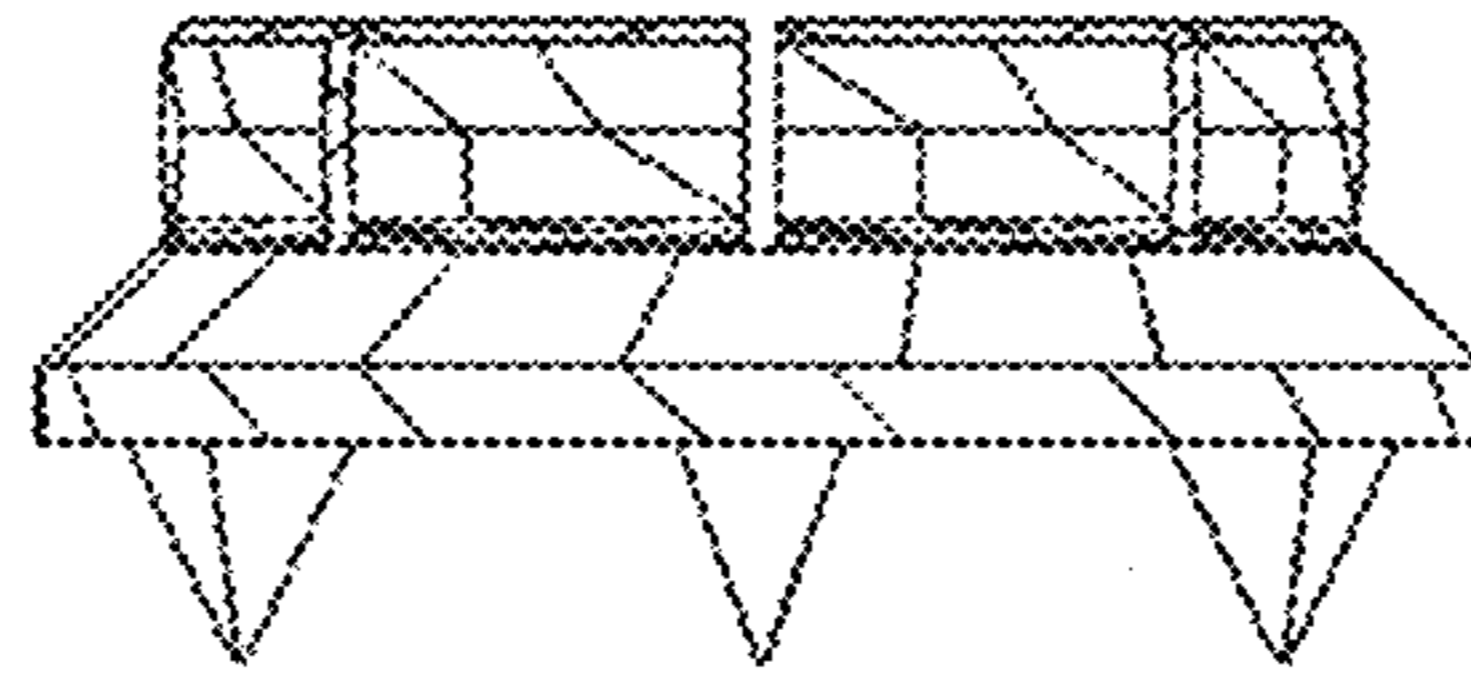


FIG. 14C

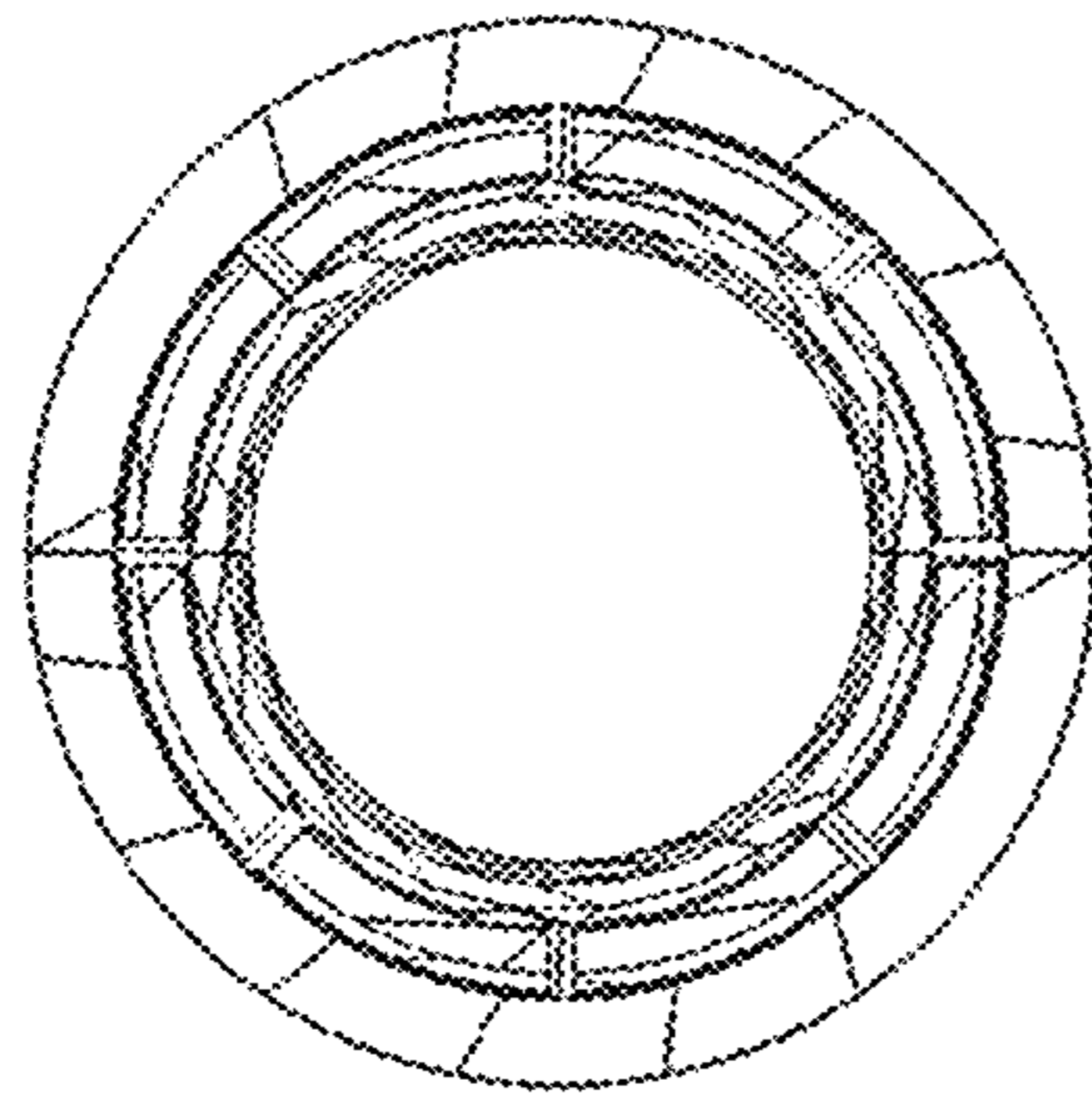


FIG. 14D

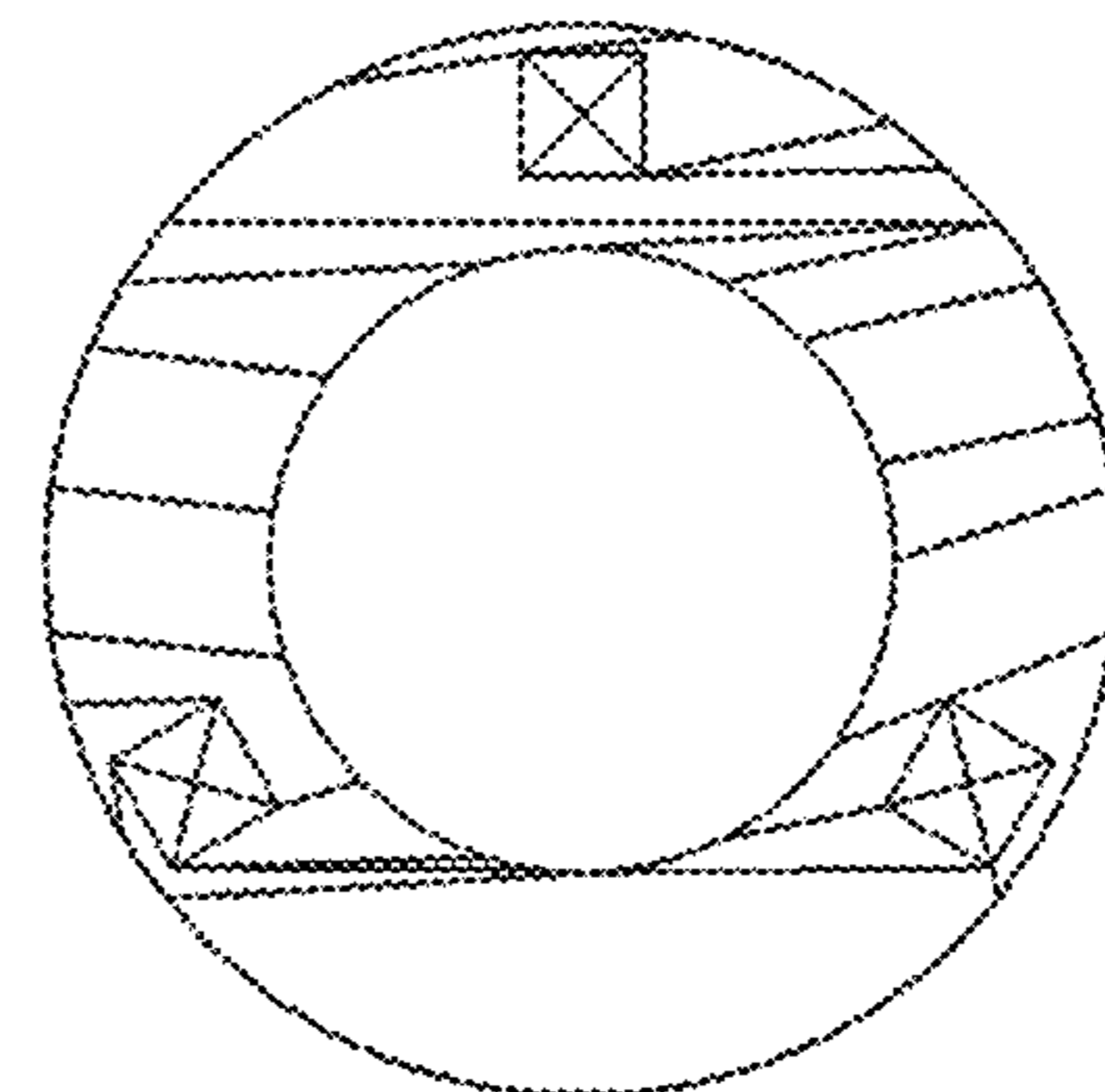


FIG. 14E

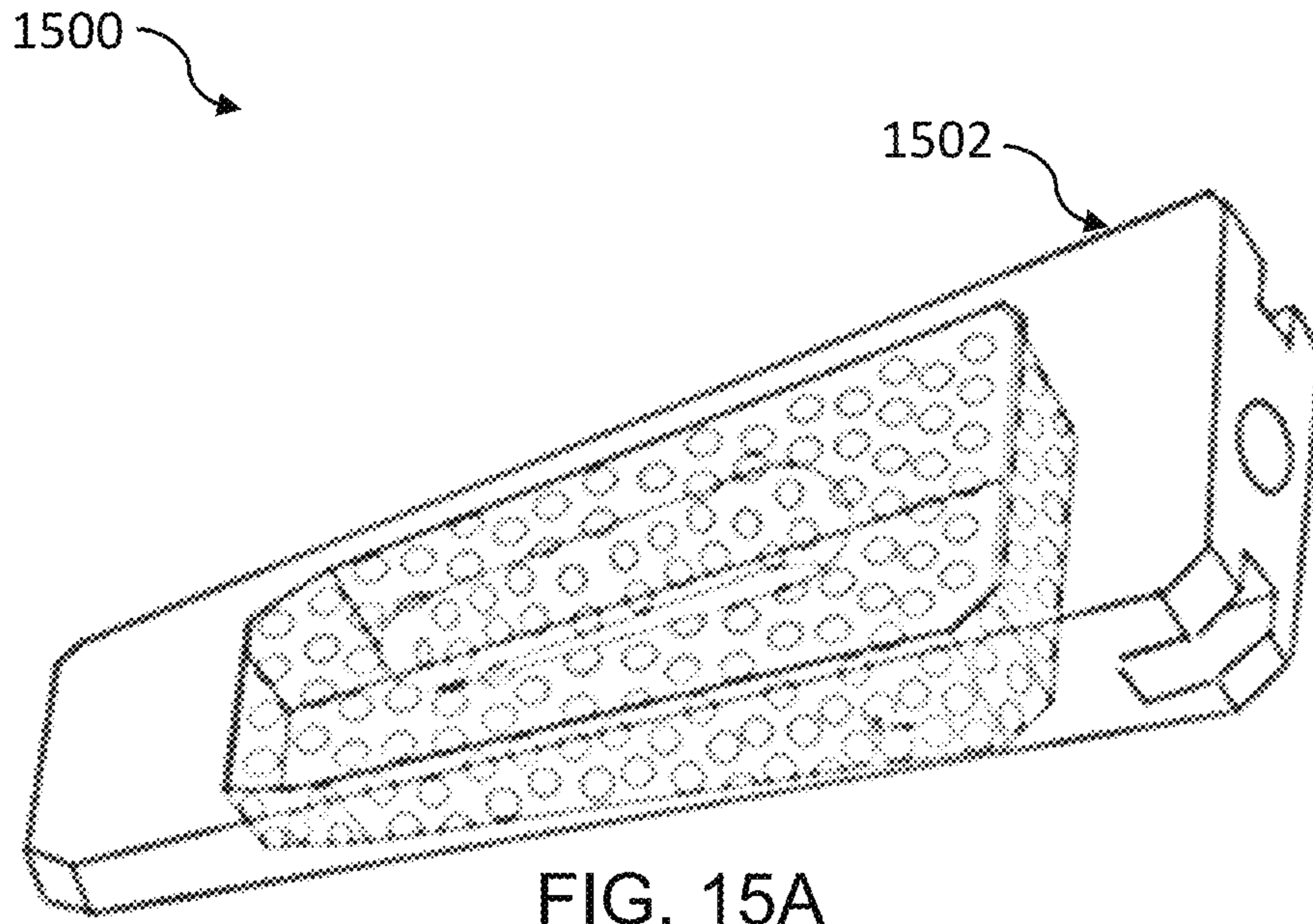


FIG. 15A

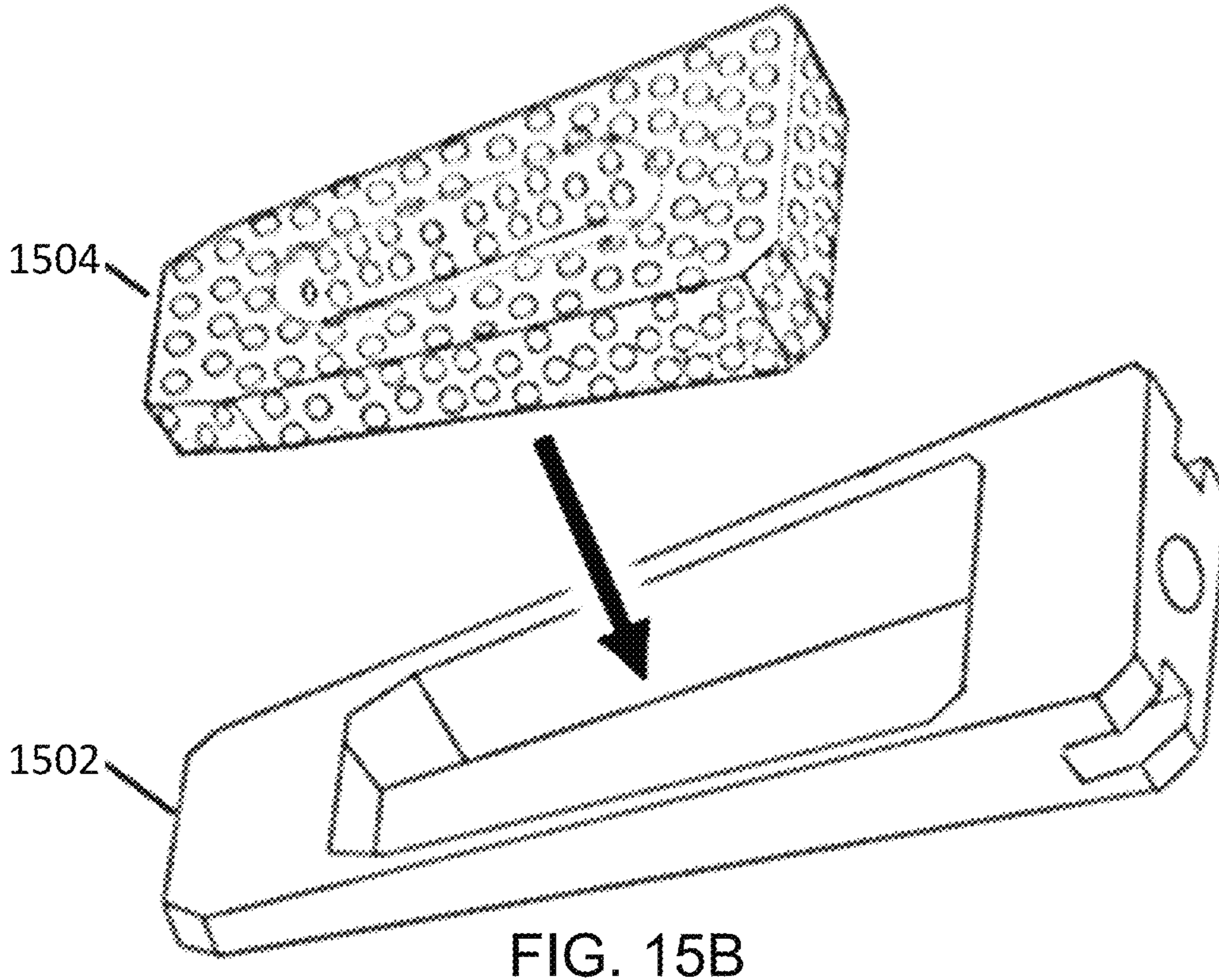


FIG. 15B

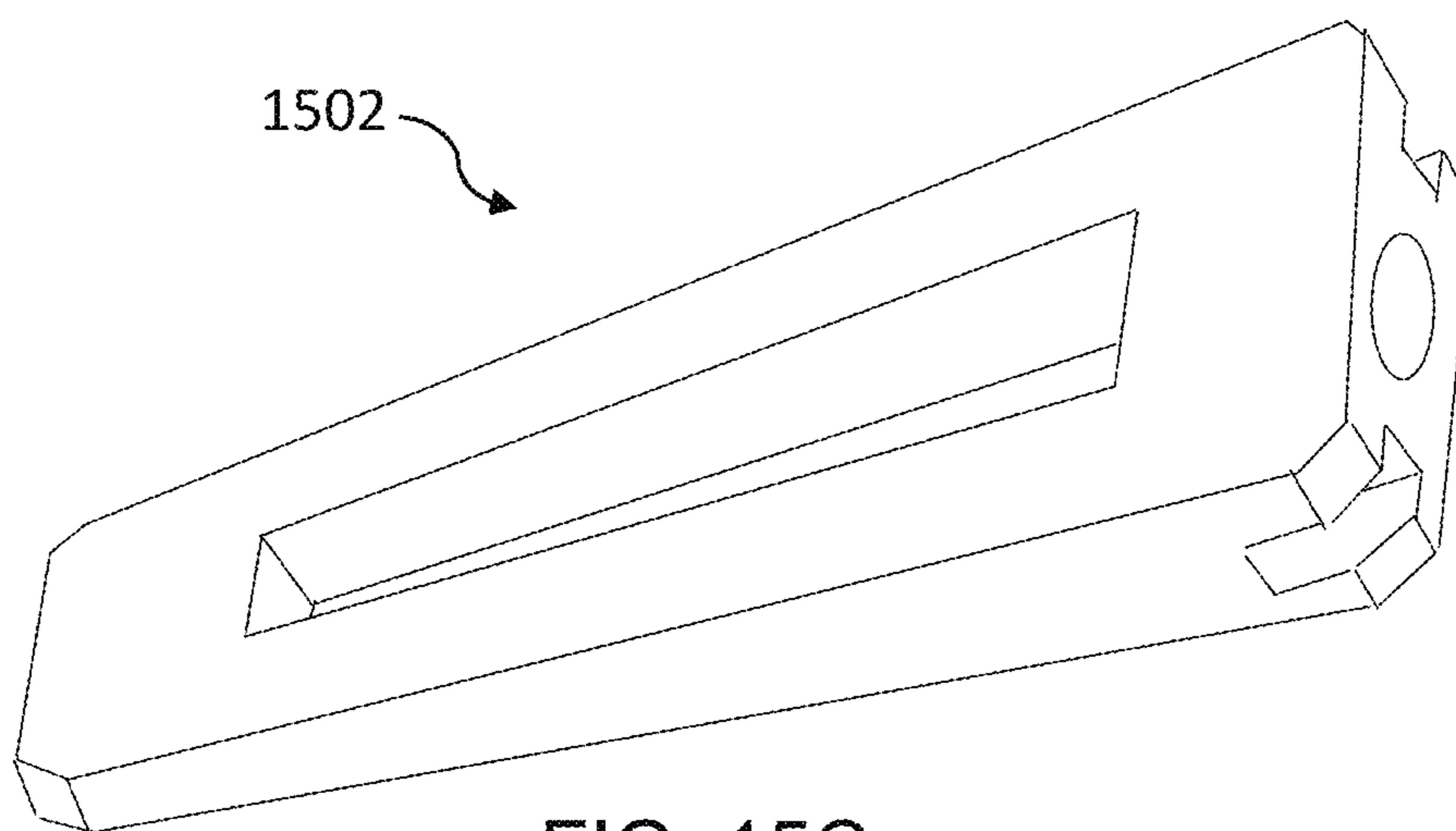


FIG. 15C

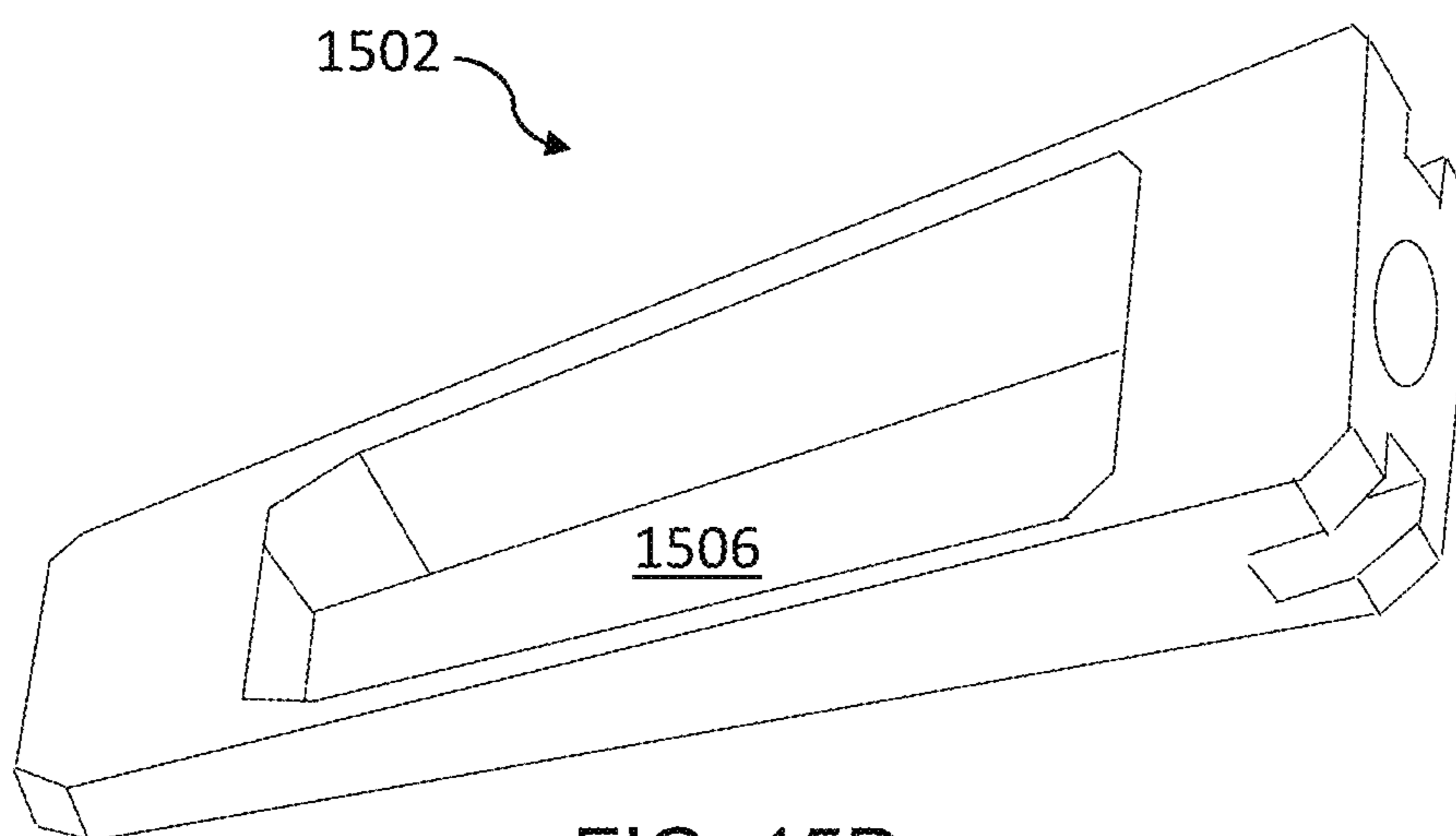


FIG. 15D

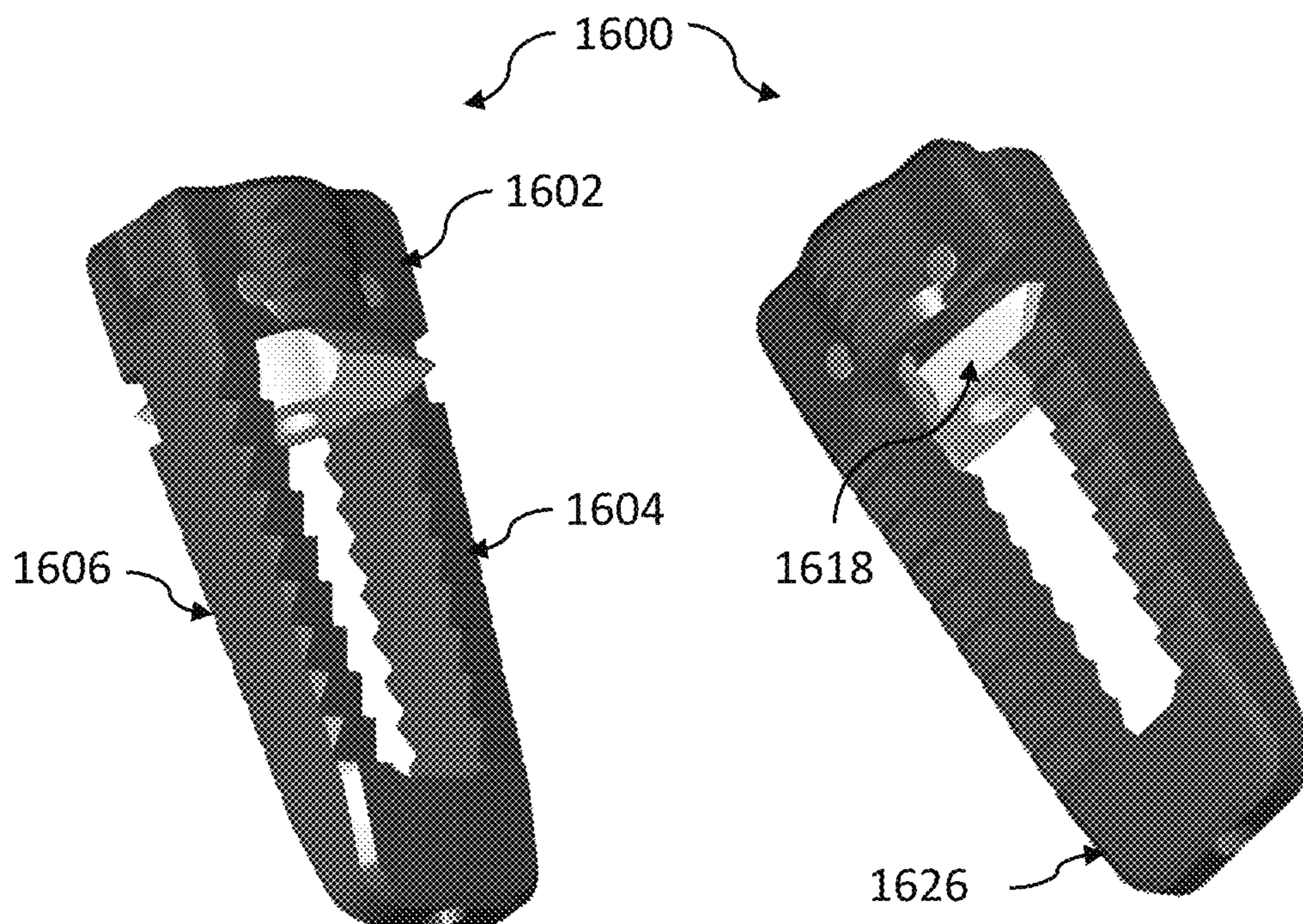


FIG. 16A

FIG. 16B

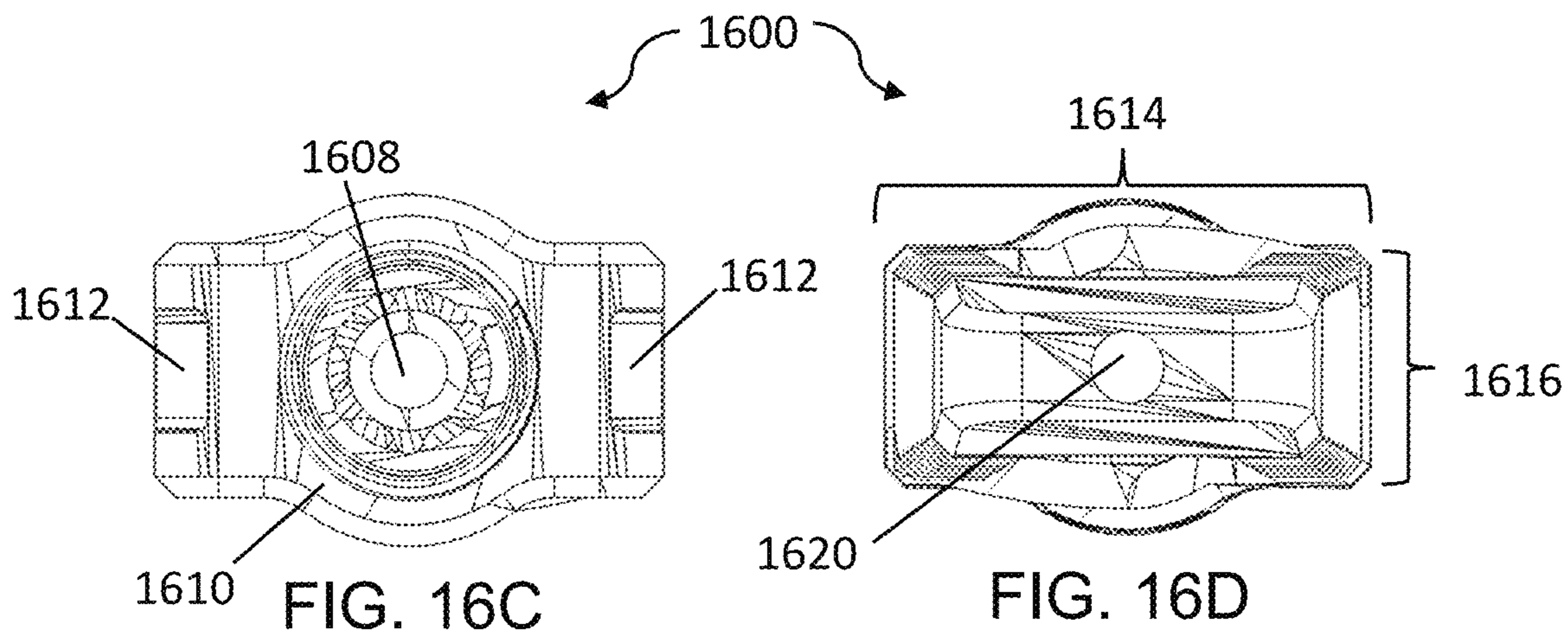


FIG. 16C

FIG. 16D

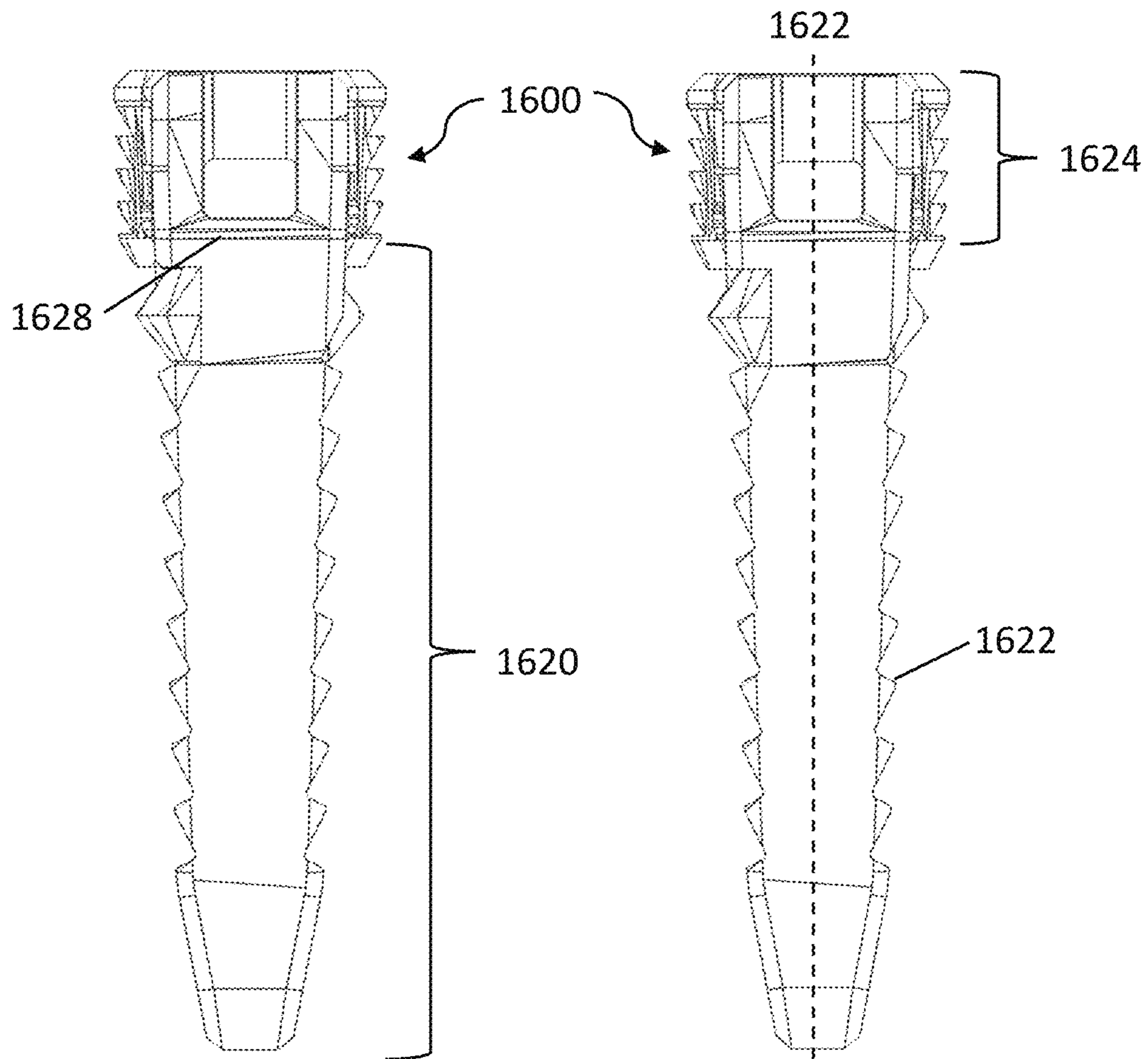


FIG. 16E

FIG. 16F

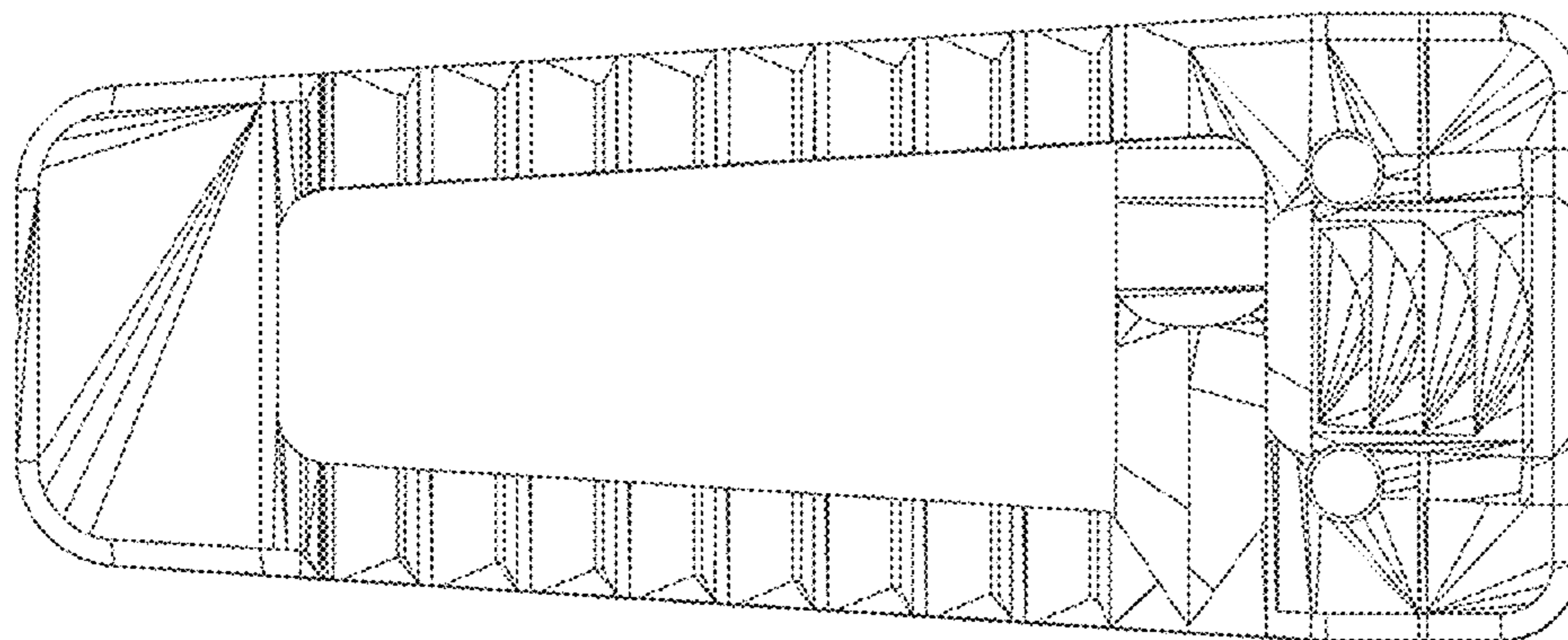


FIG. 16G

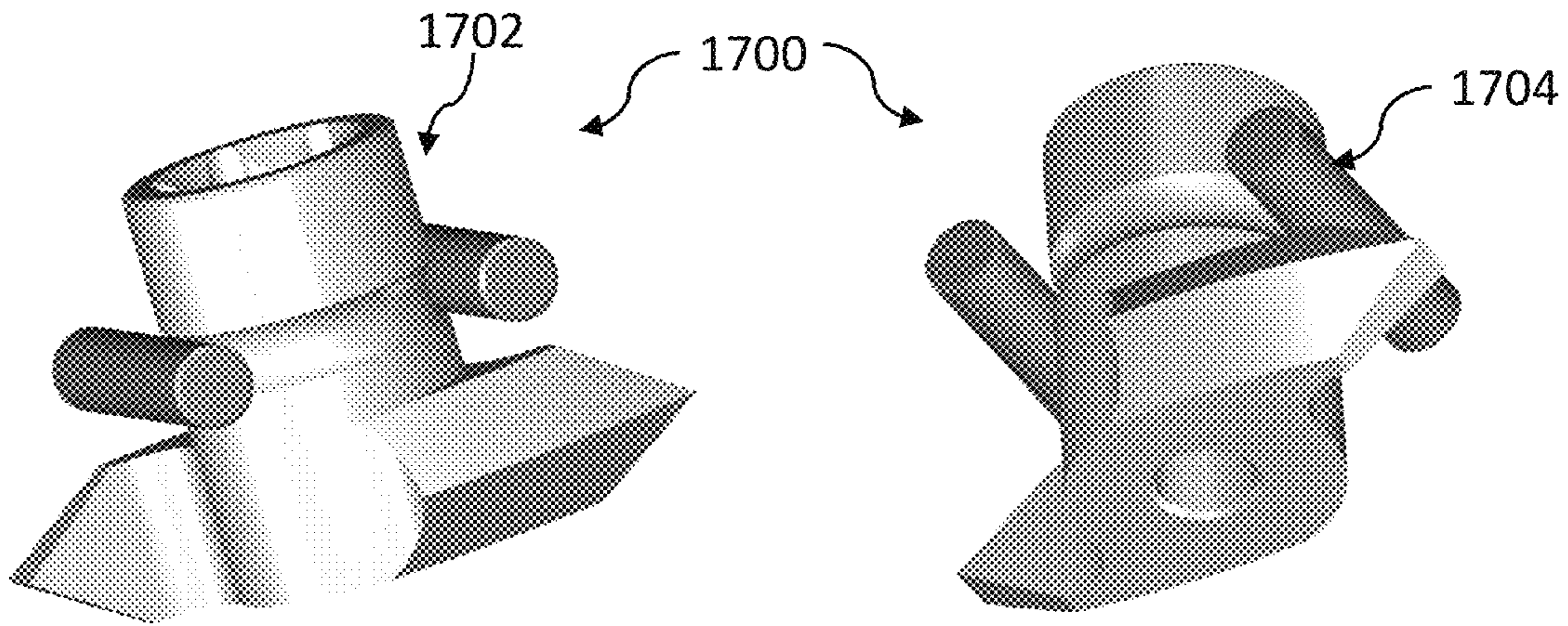


FIG. 17A

FIG. 17B

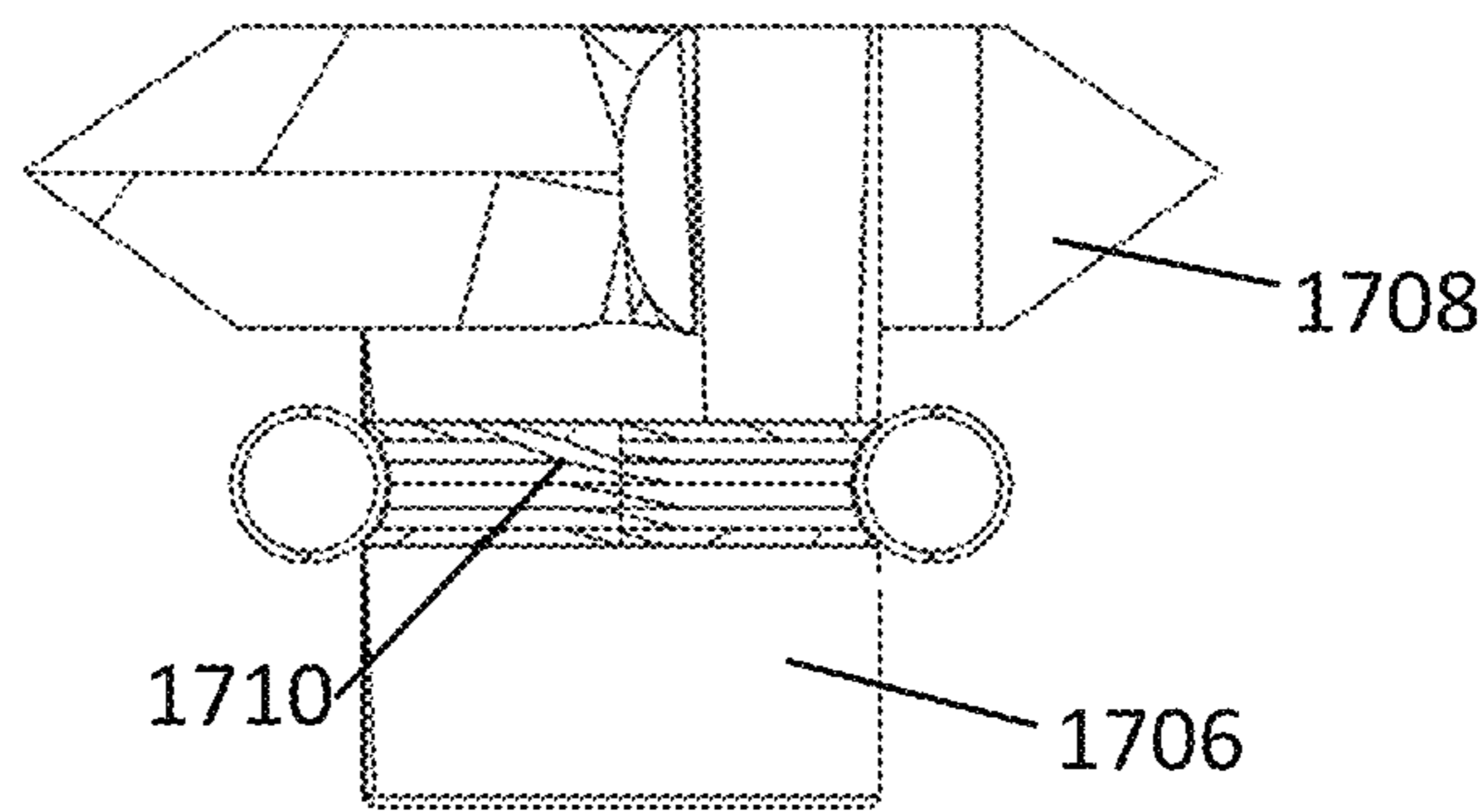


FIG. 17C

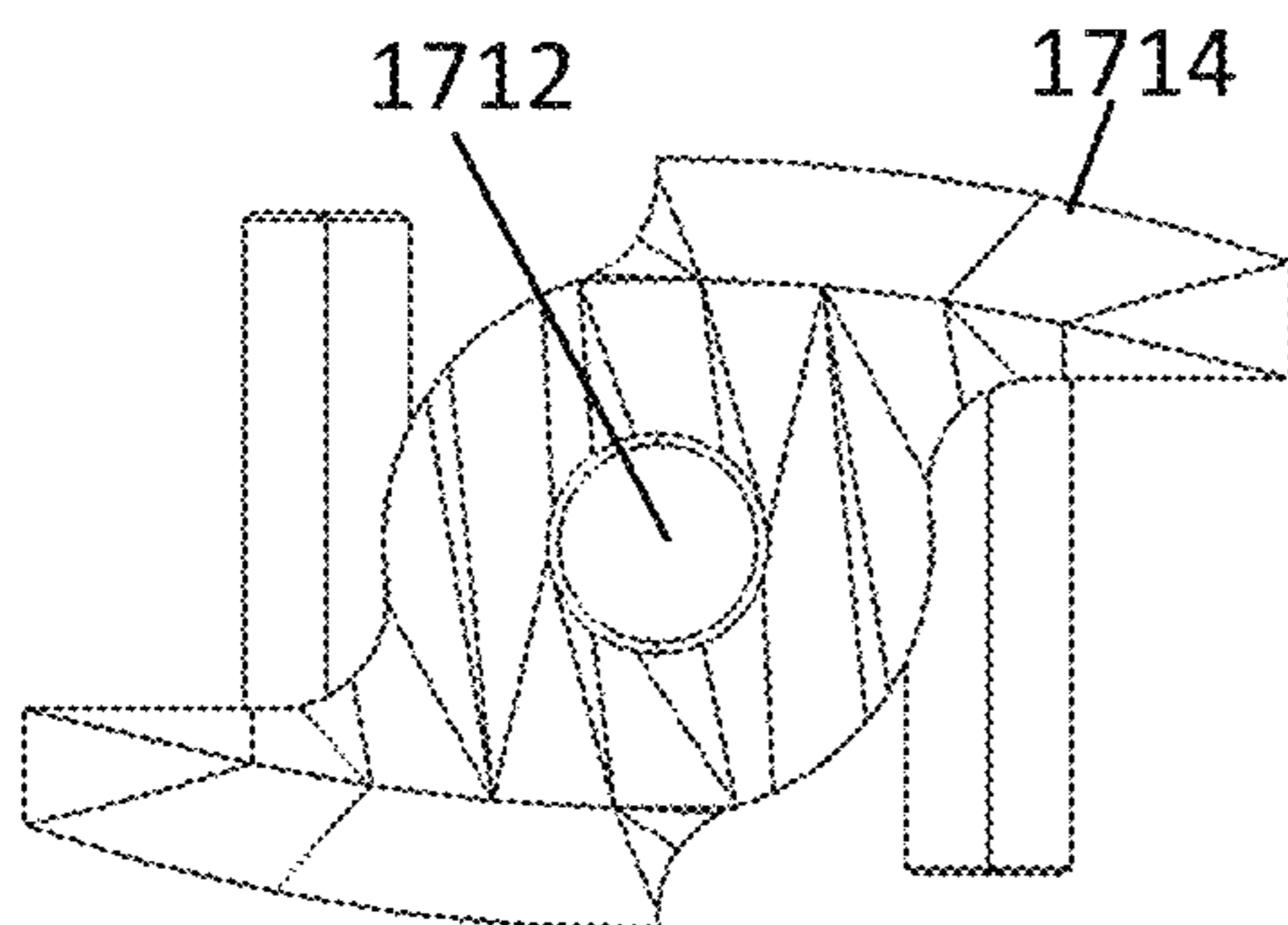


FIG. 17D

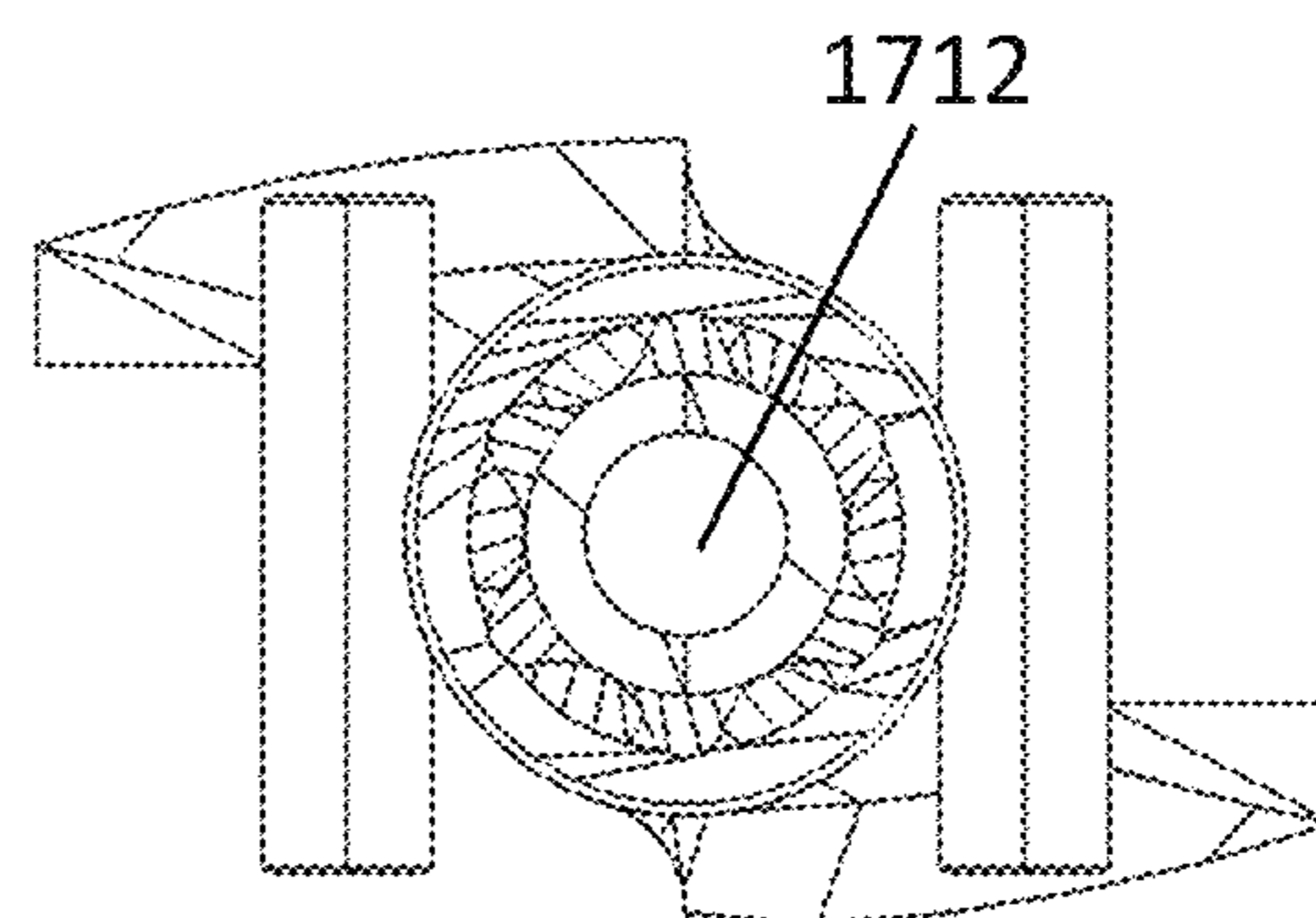


FIG. 17E

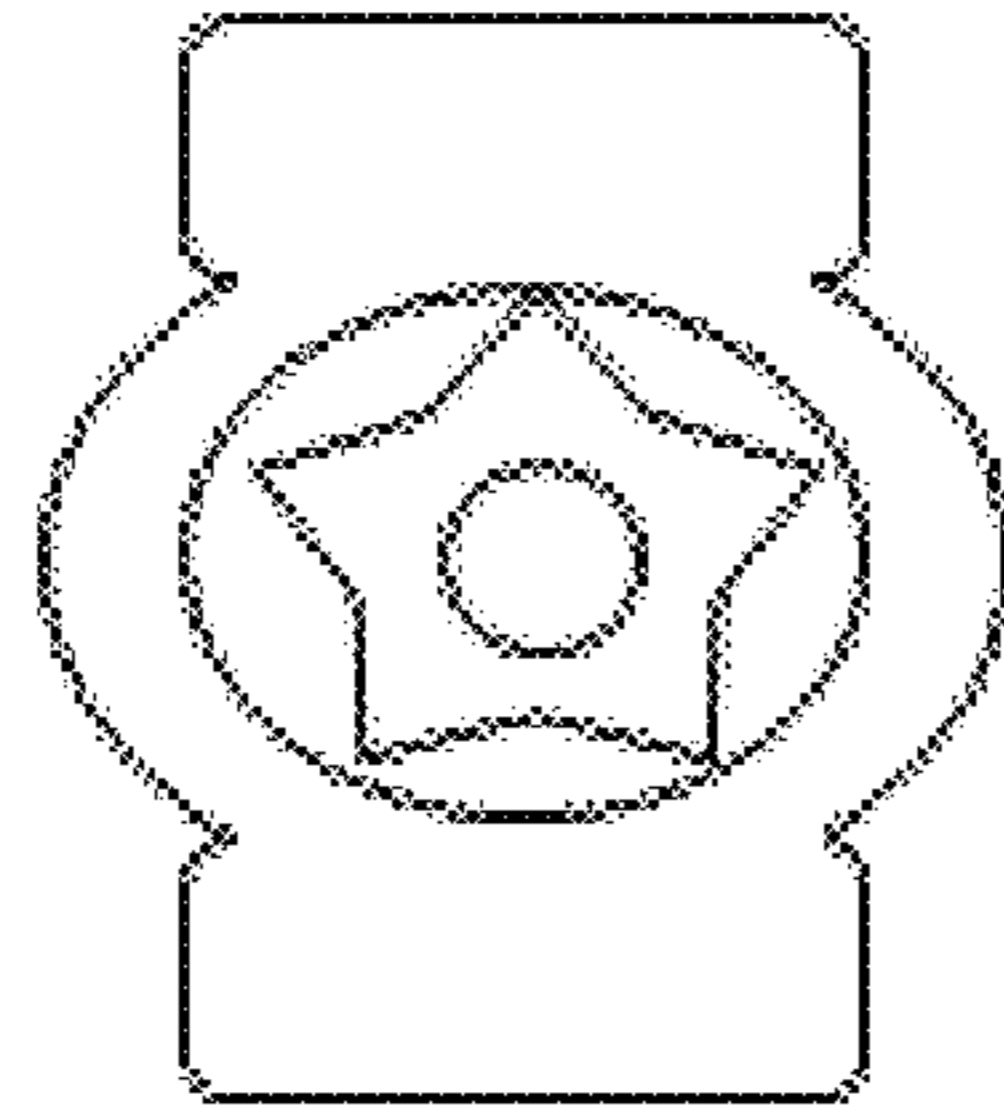


FIG. 18A

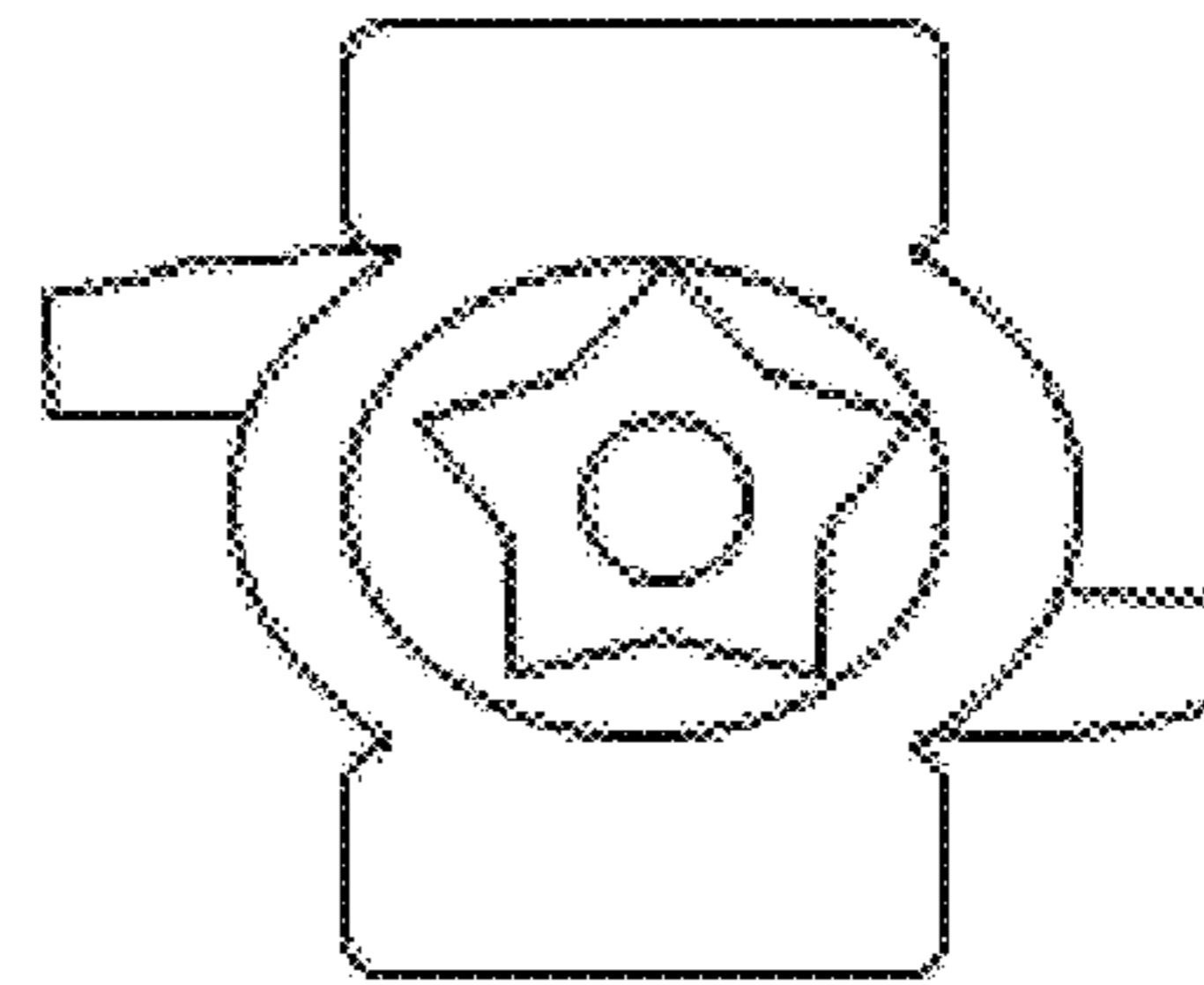
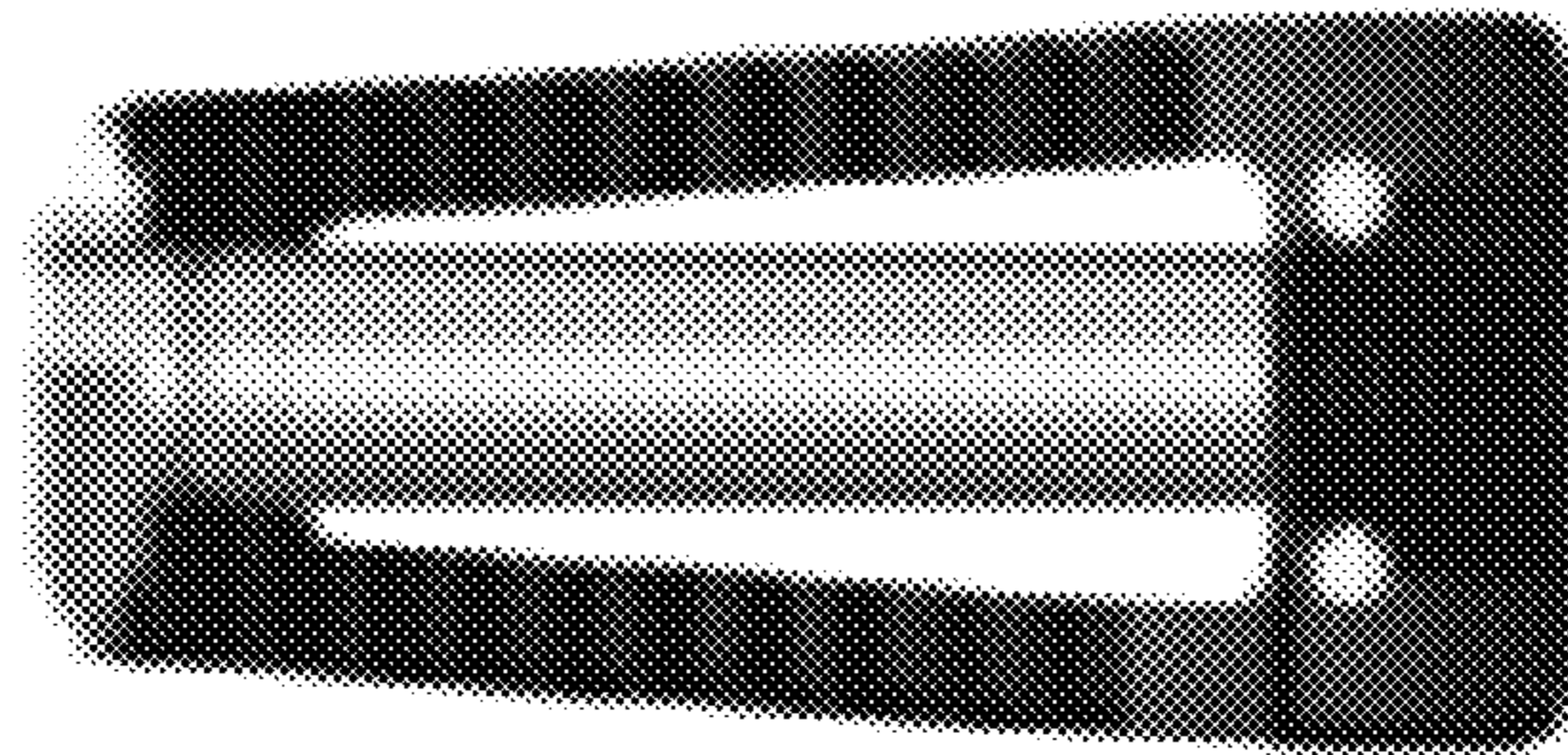


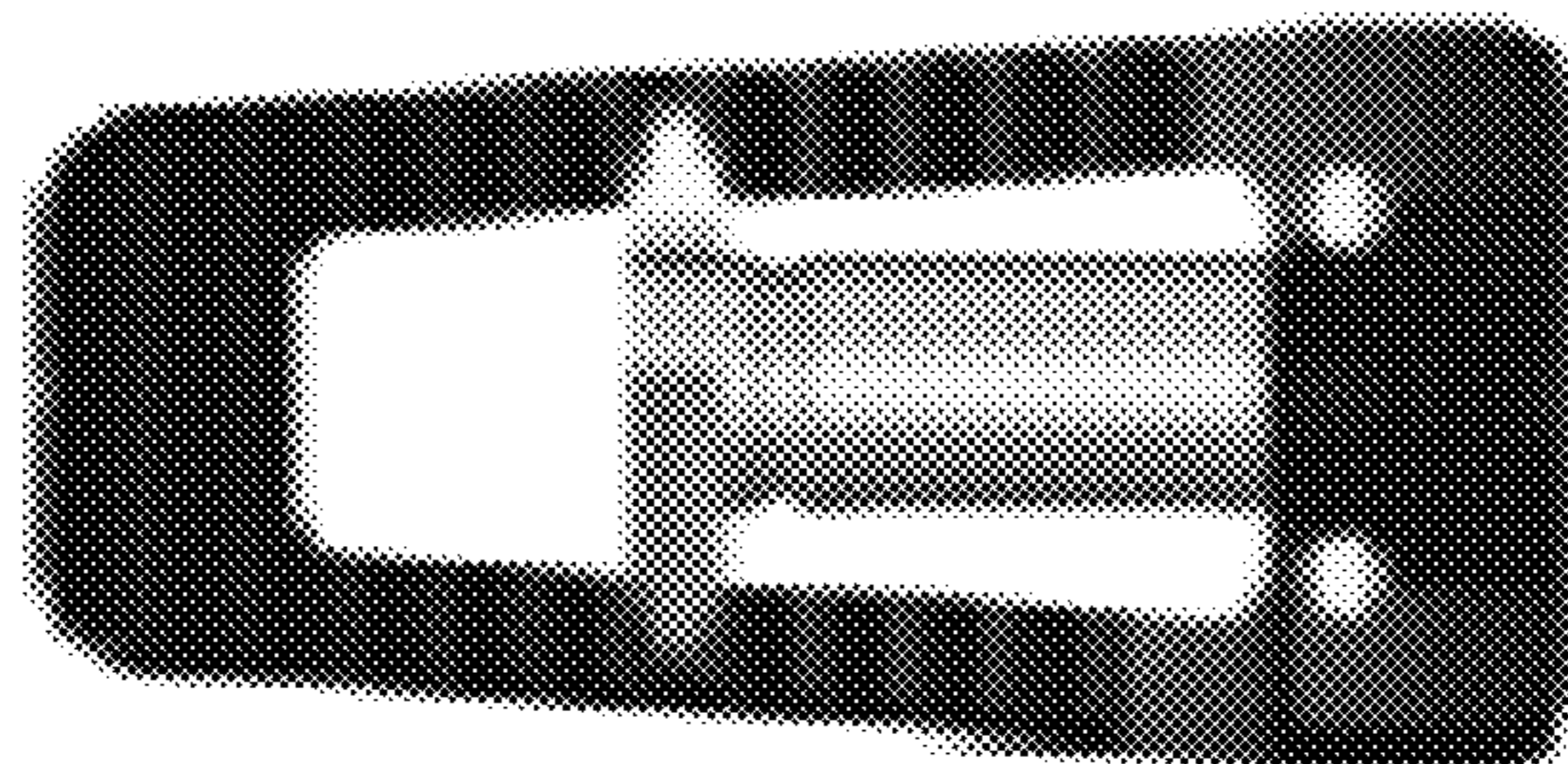
FIG. 18B

FIG. 19A



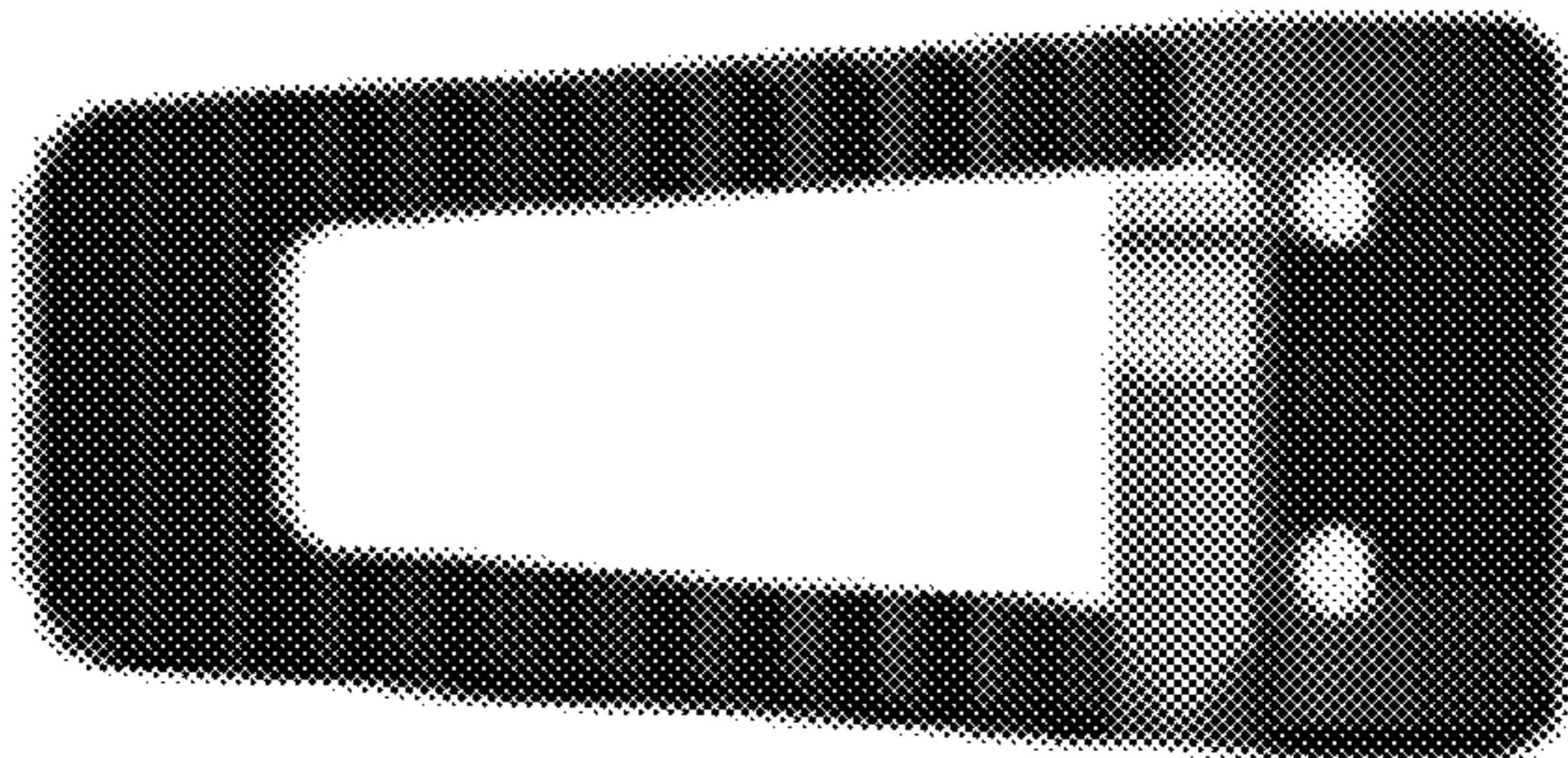
1902

FIG. 19B



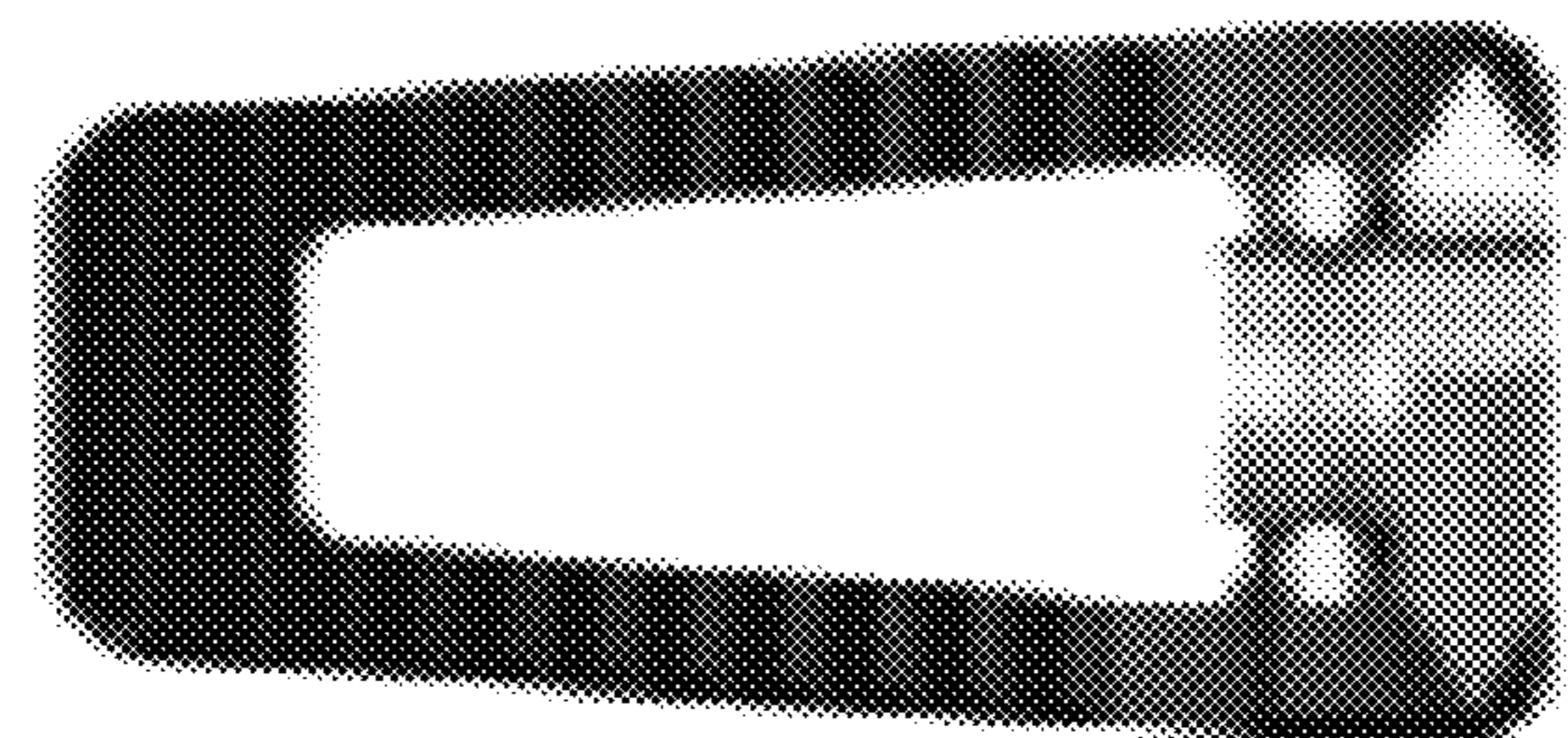
1904

FIG. 19C



1906

FIG. 19D



1908

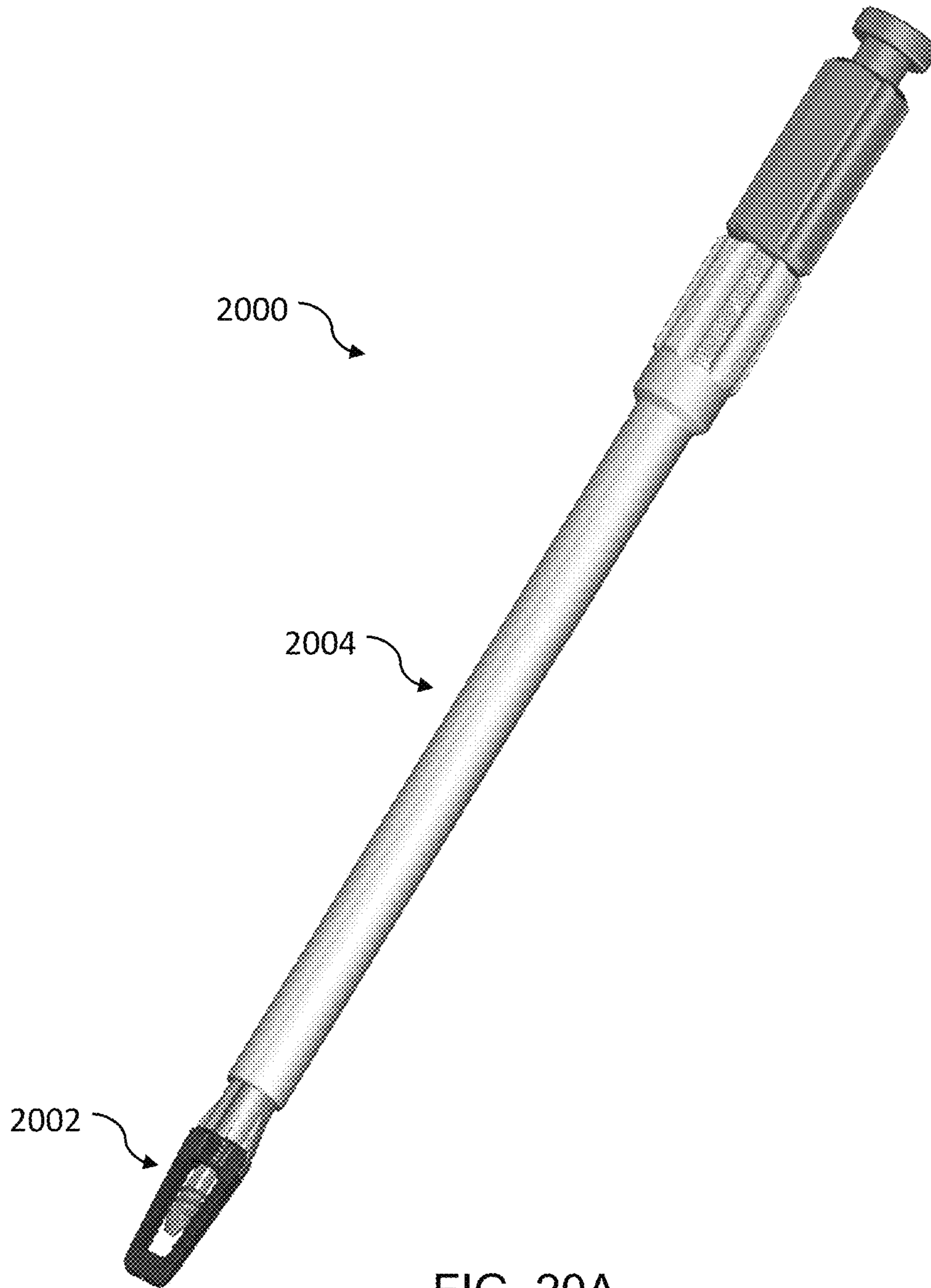


FIG. 20A

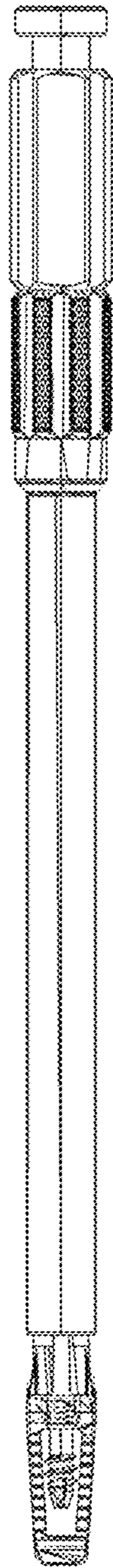


FIG. 20B

2000

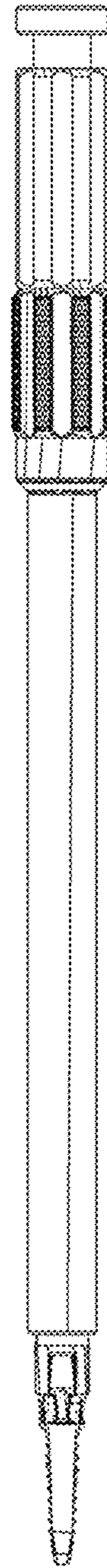


FIG. 20C

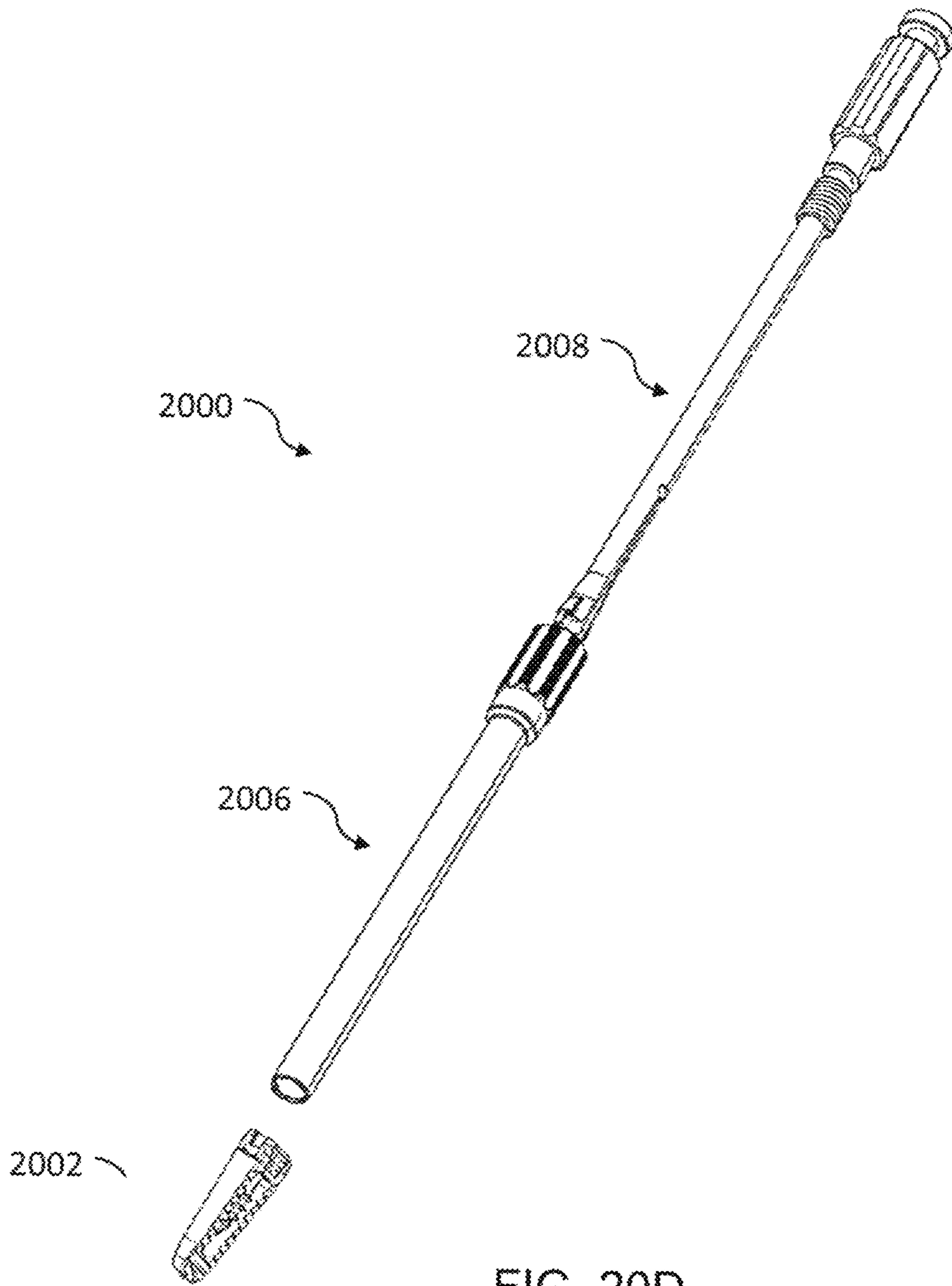


FIG. 20D

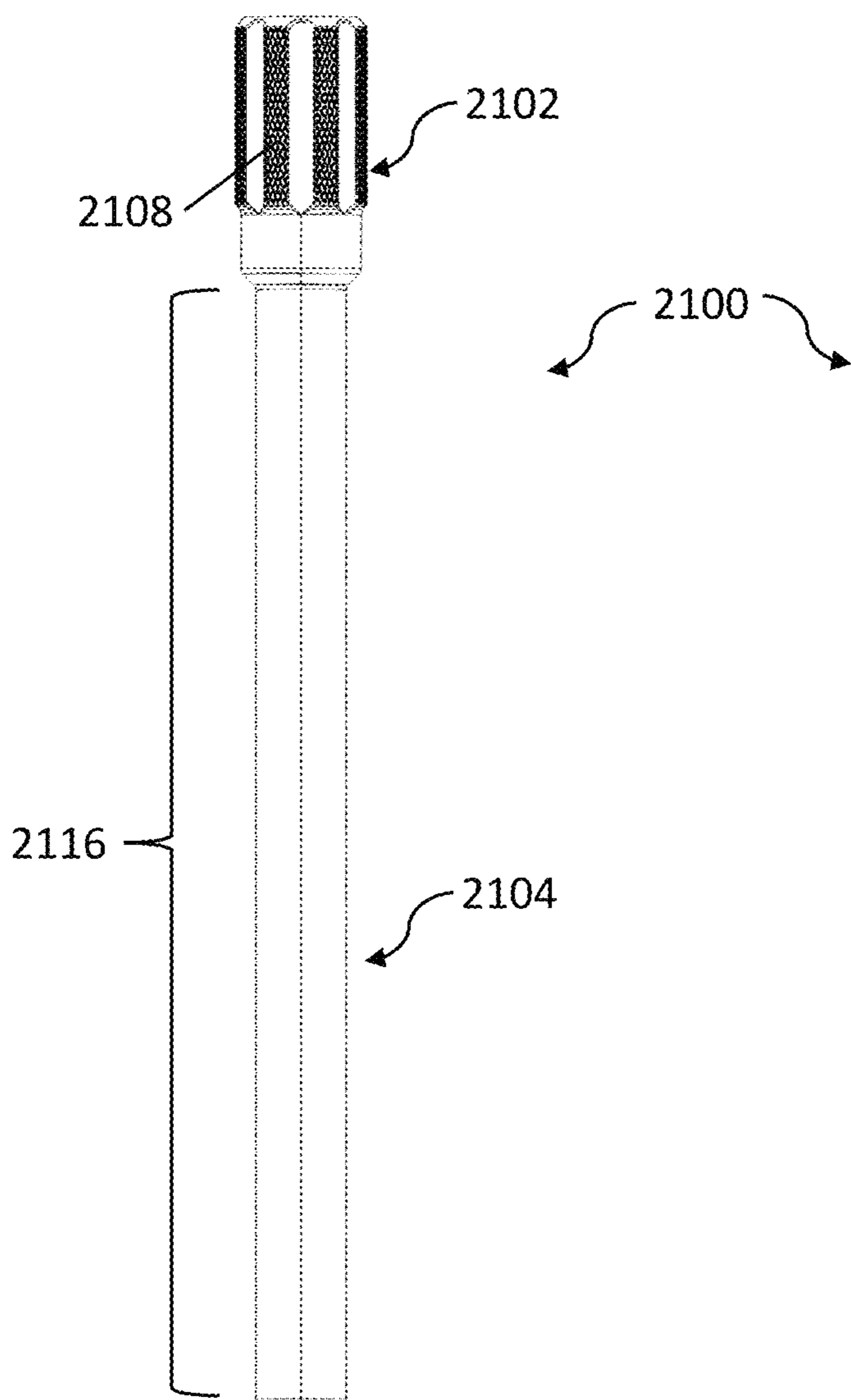


FIG. 21A

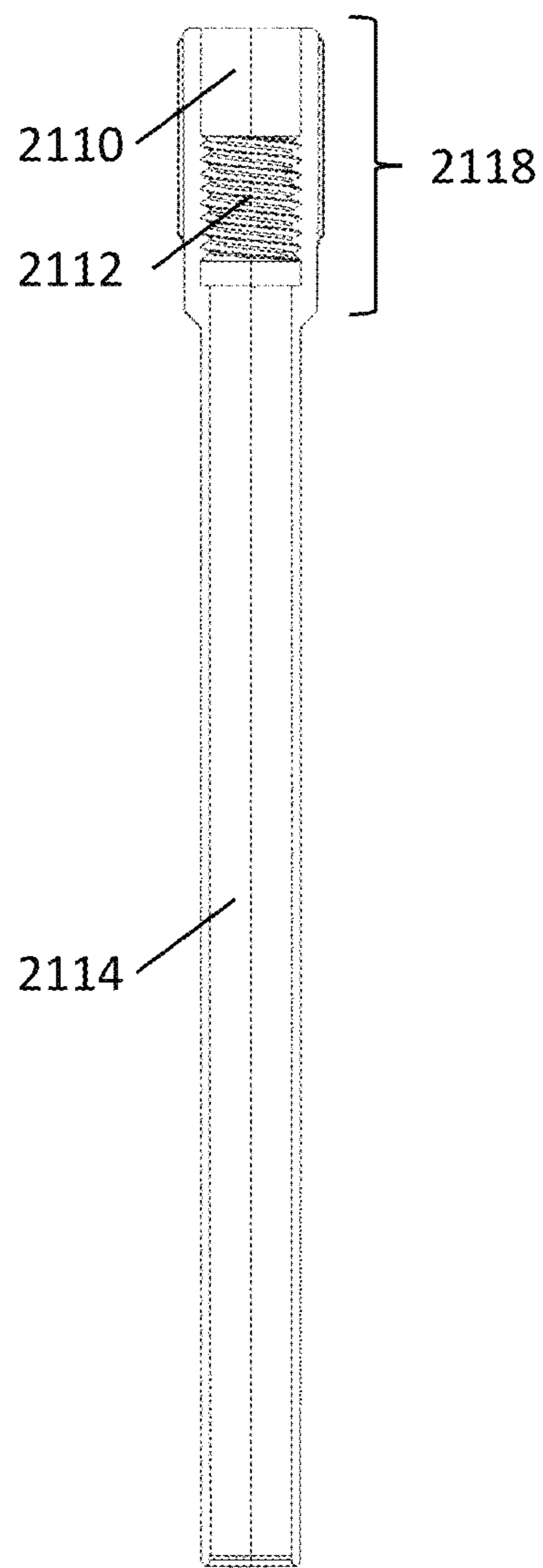


FIG. 21B

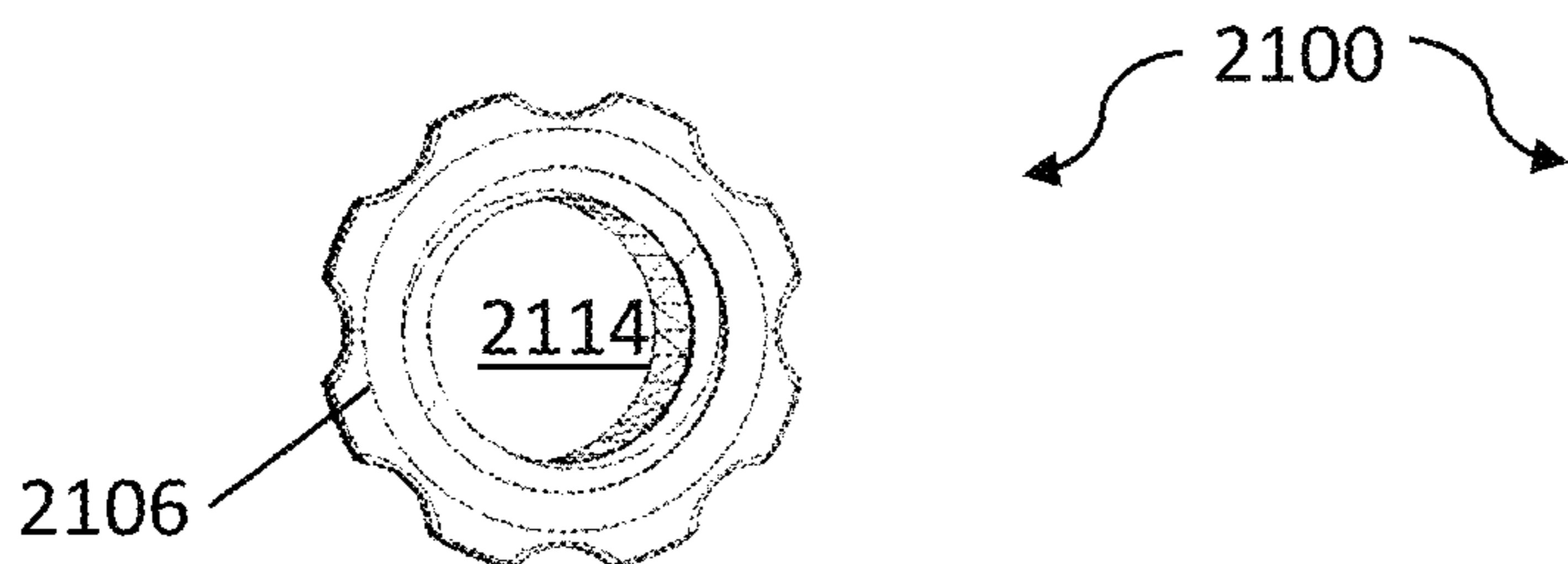


FIG. 21C

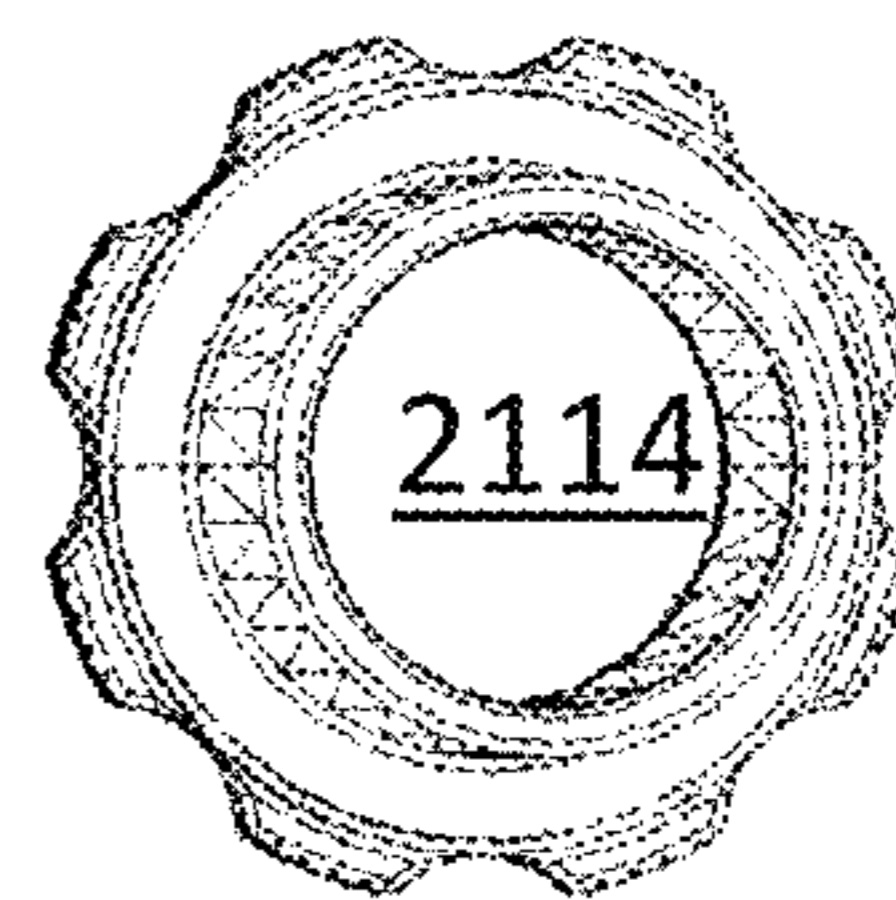


FIG. 21D

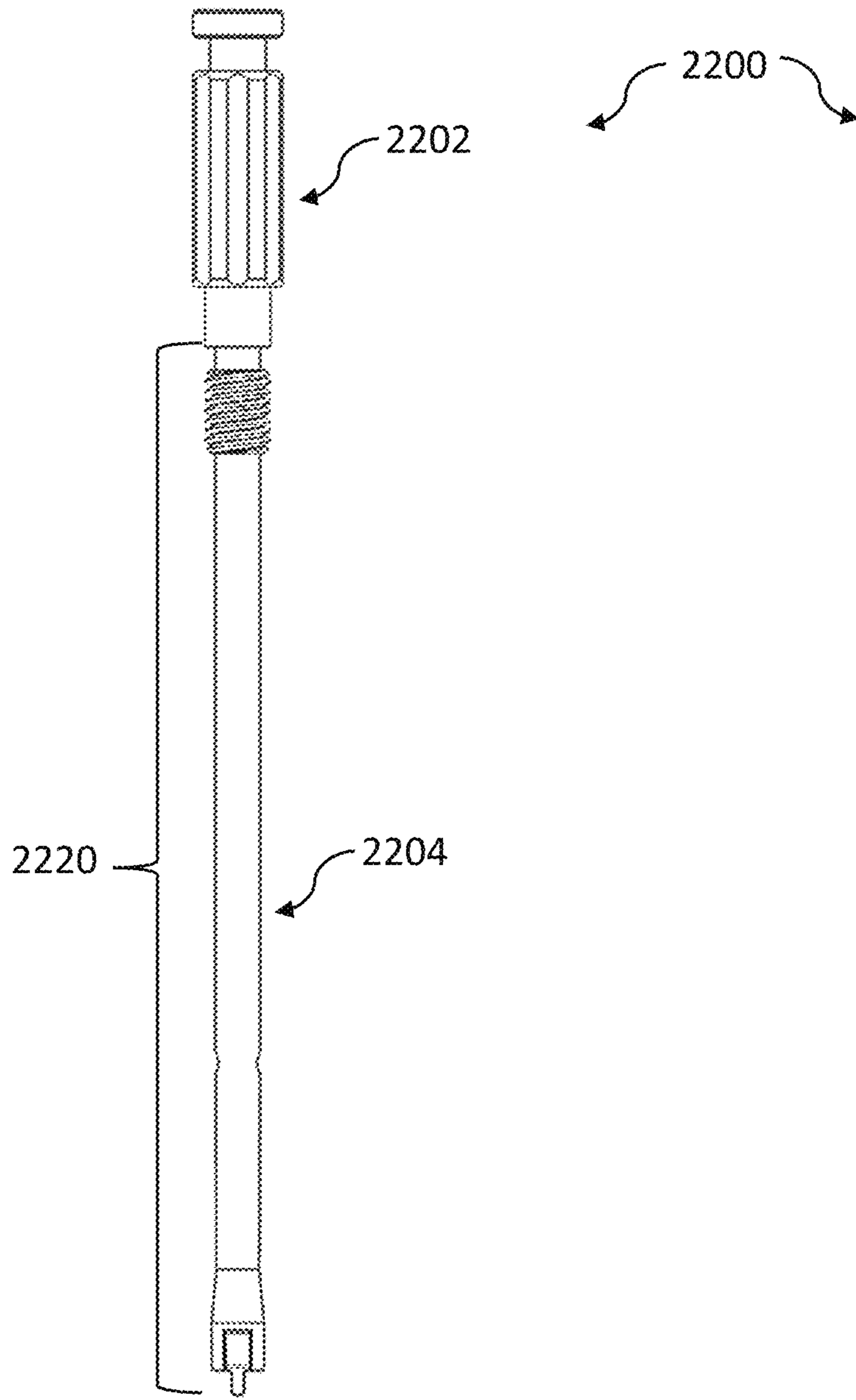


FIG. 22A

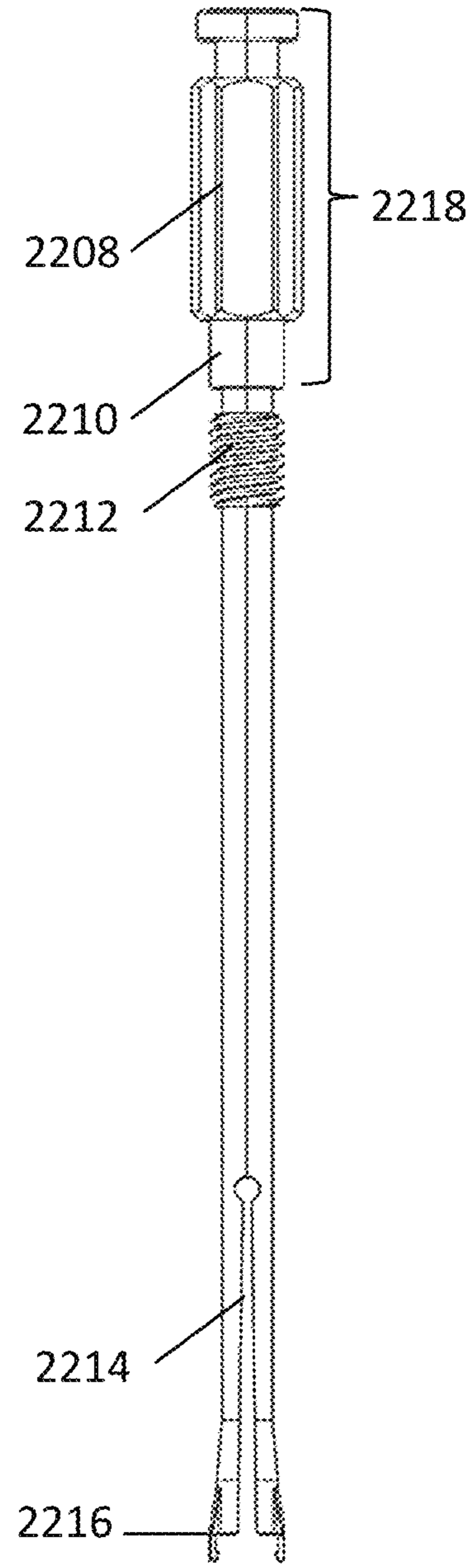


FIG. 22B

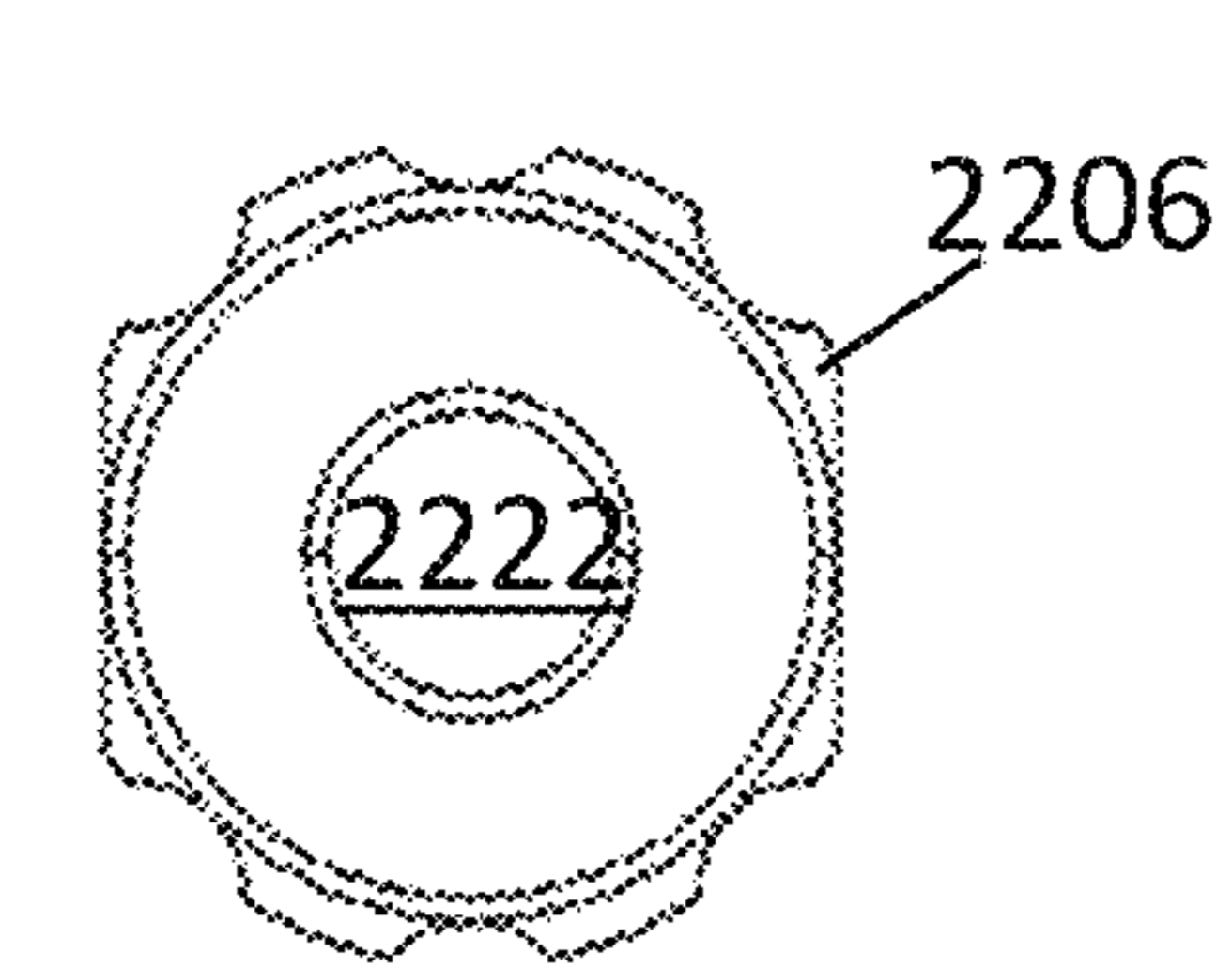


FIG. 22C

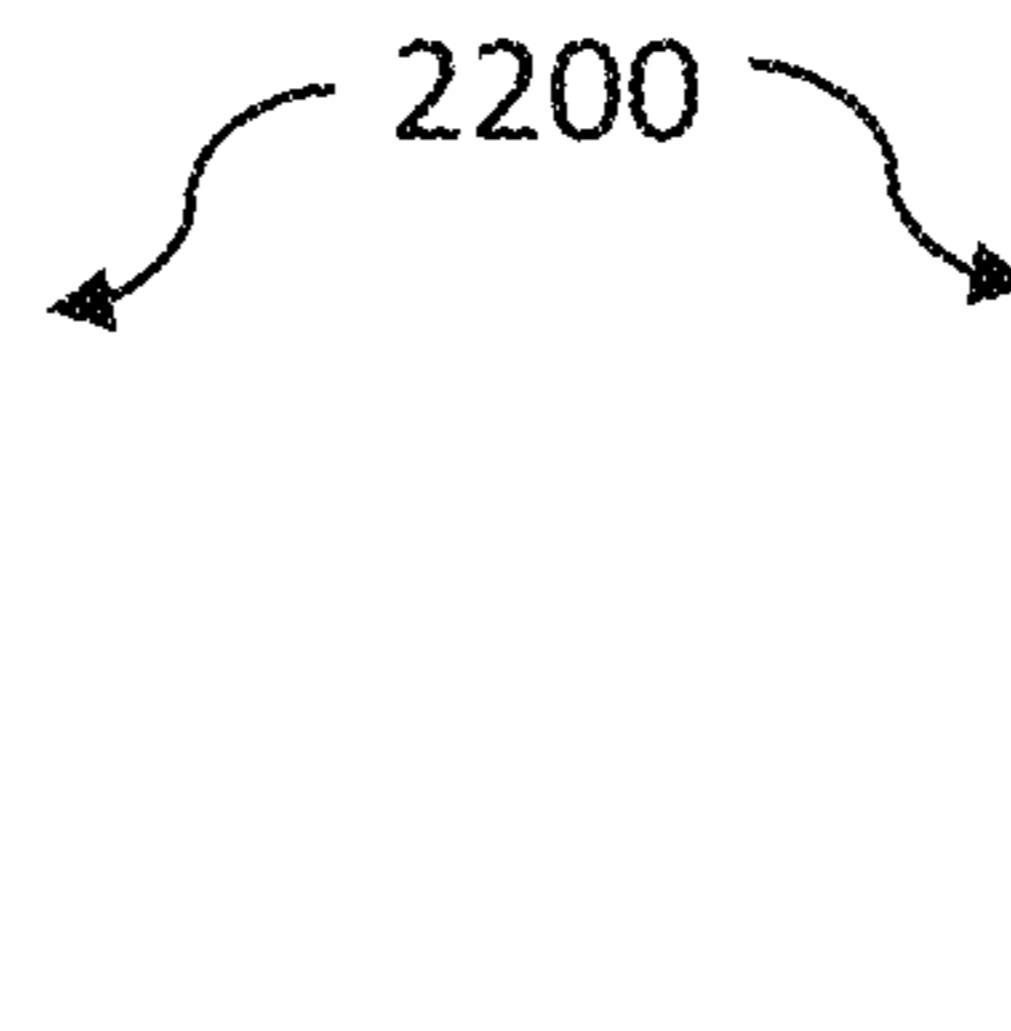


FIG. 22D

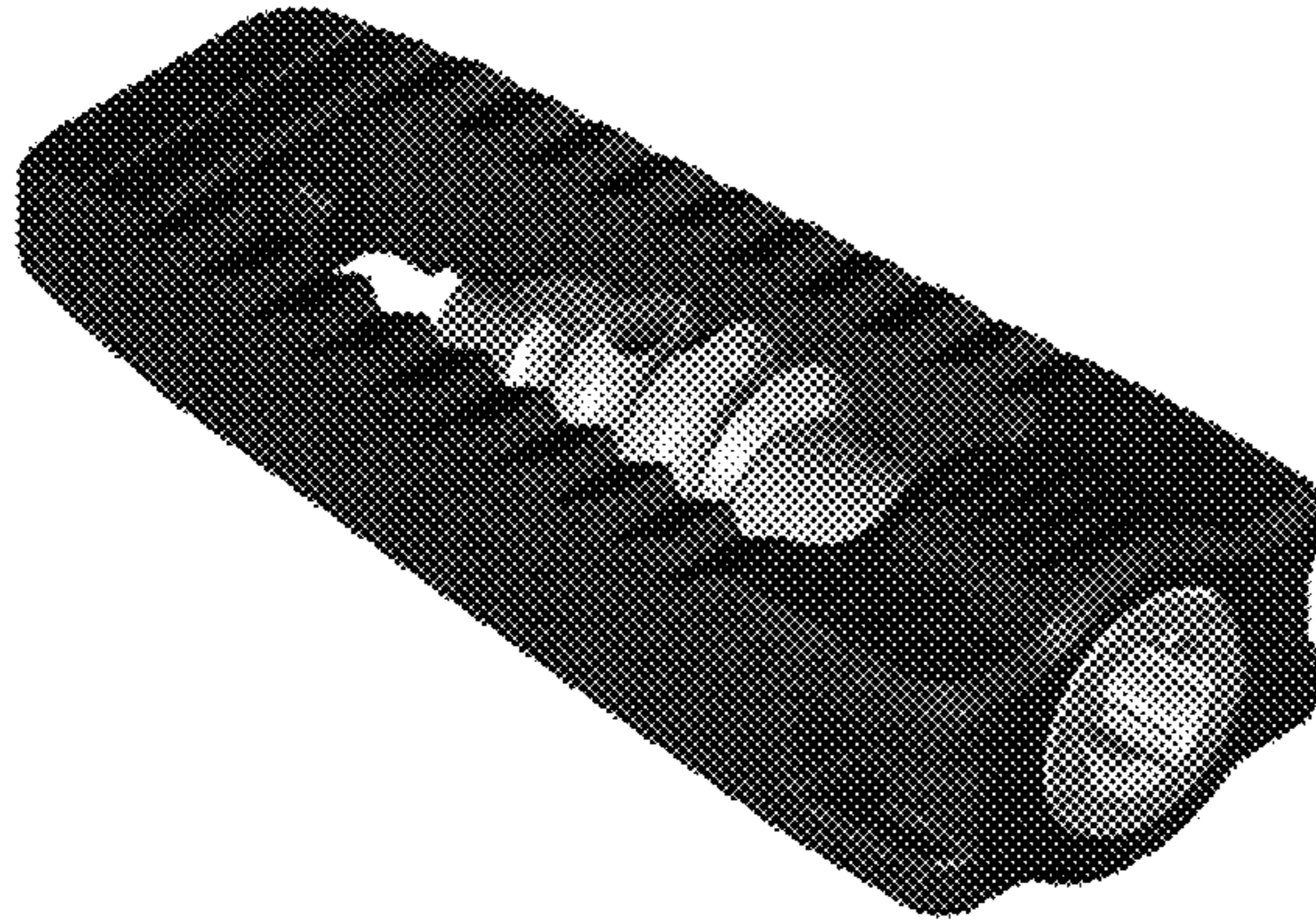


FIG. 23A

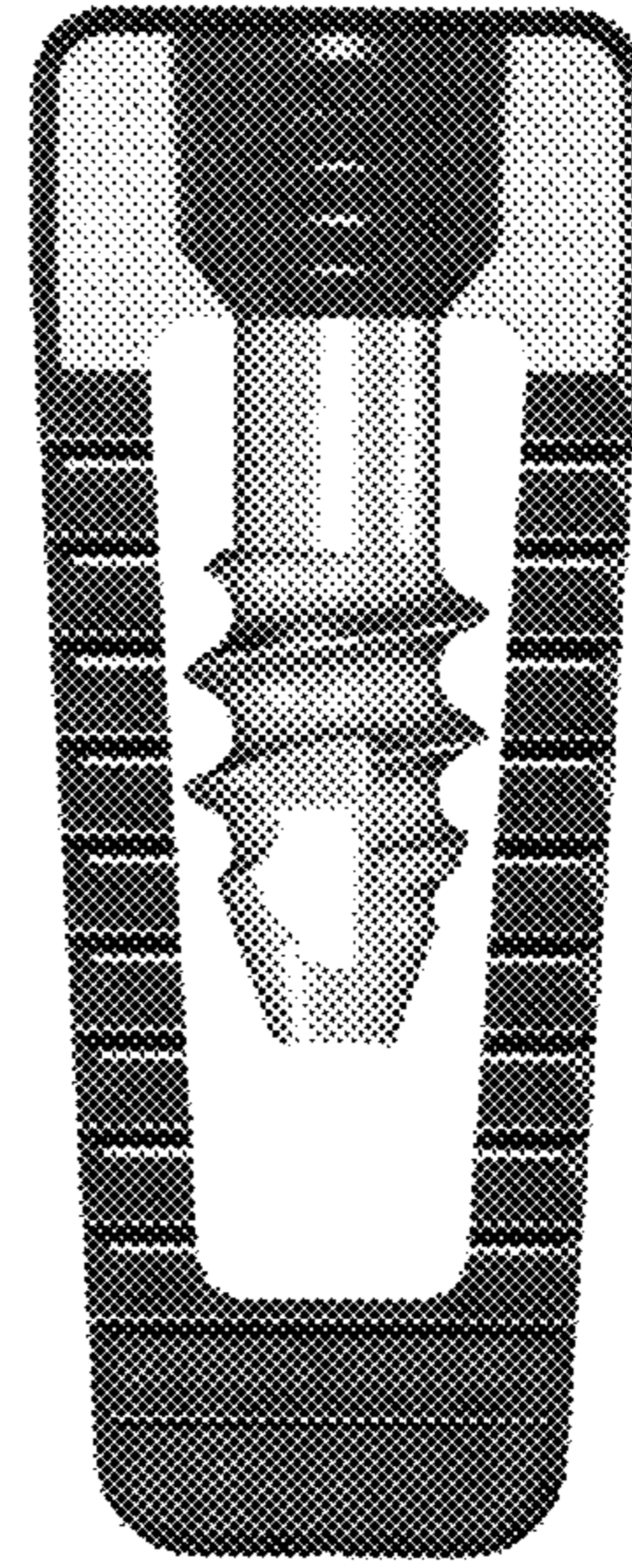


FIG. 23B

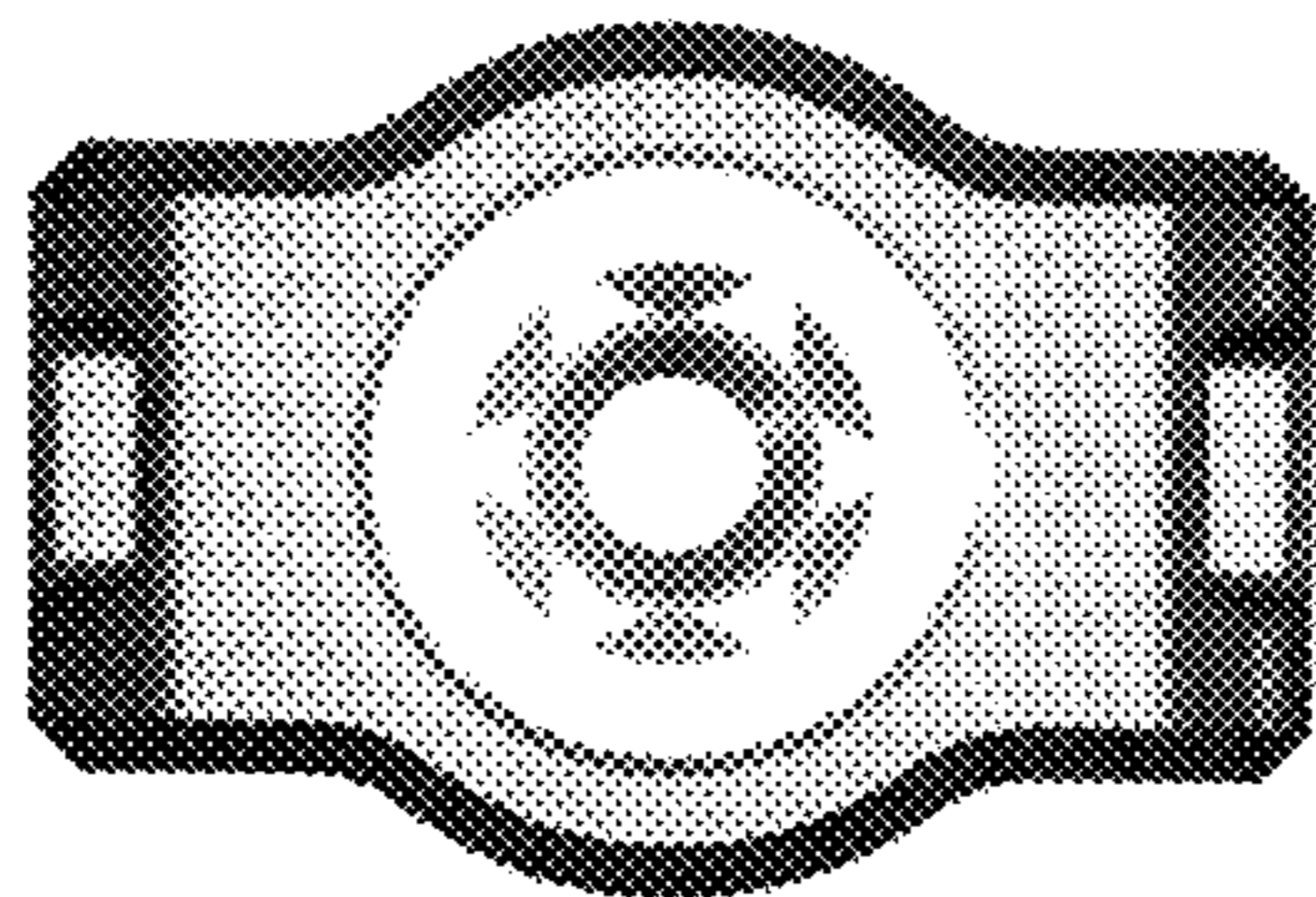


FIG. 23C

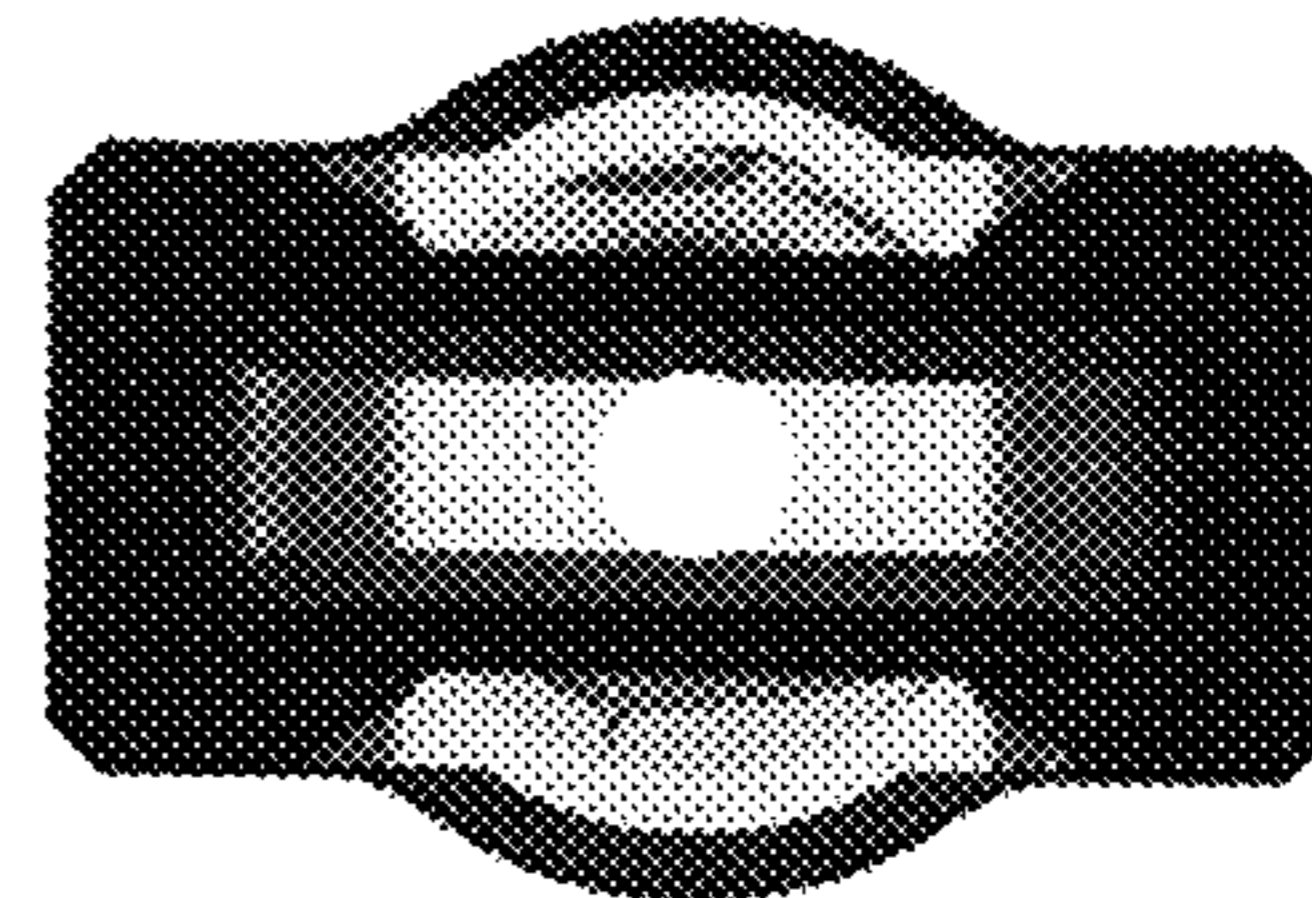


FIG. 23D

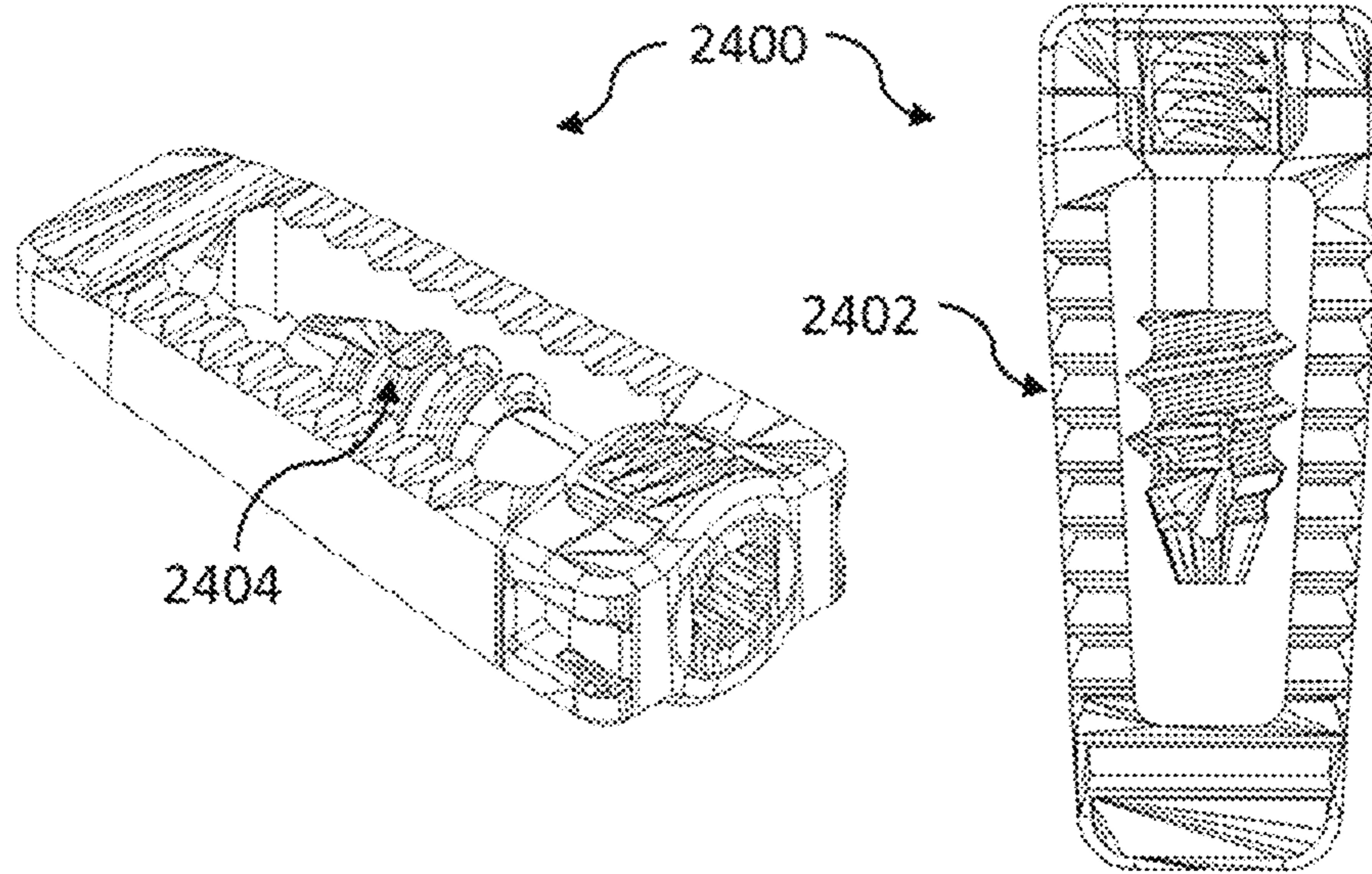


FIG. 24A

FIG. 24B

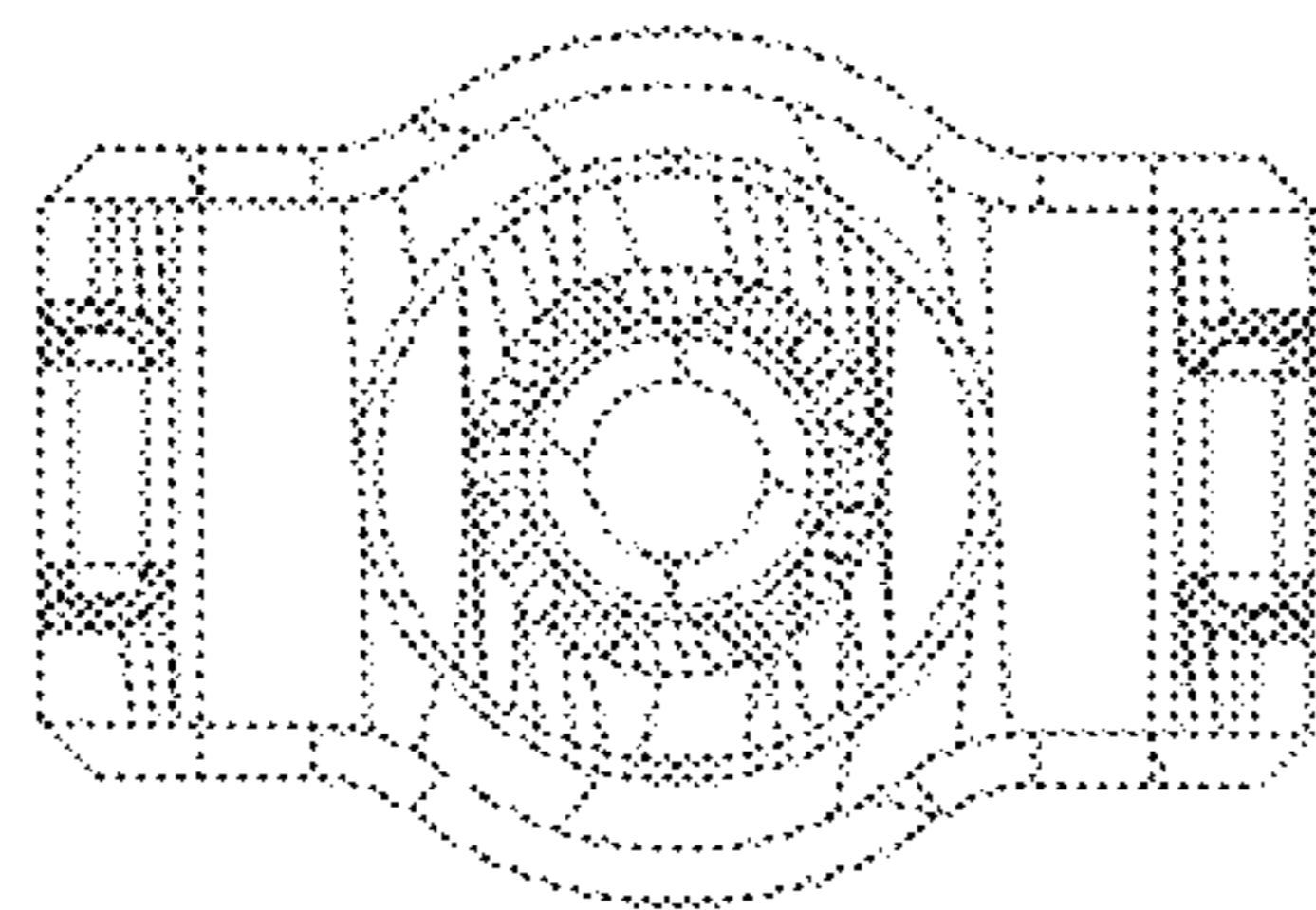


FIG. 24C

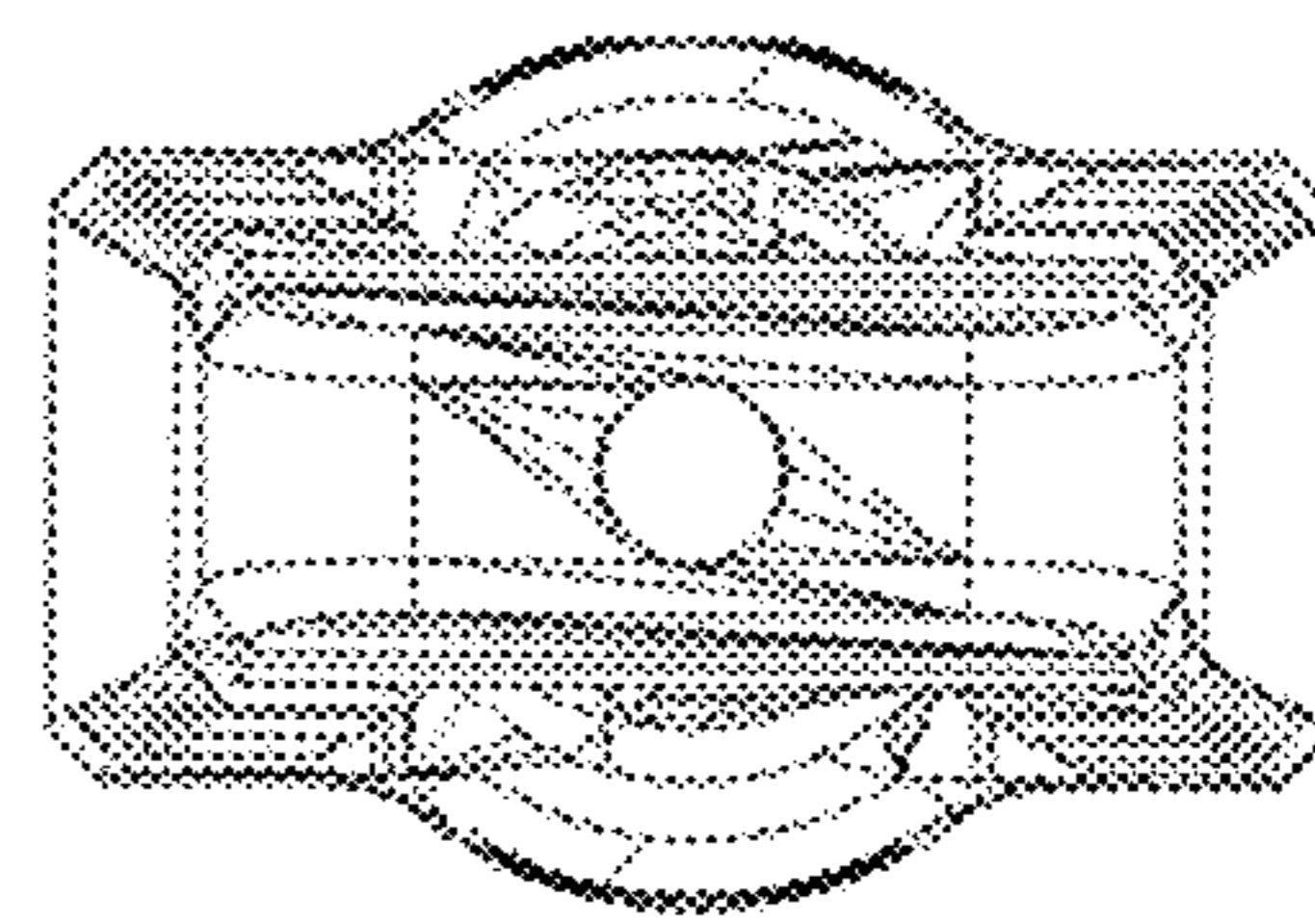


FIG. 24D

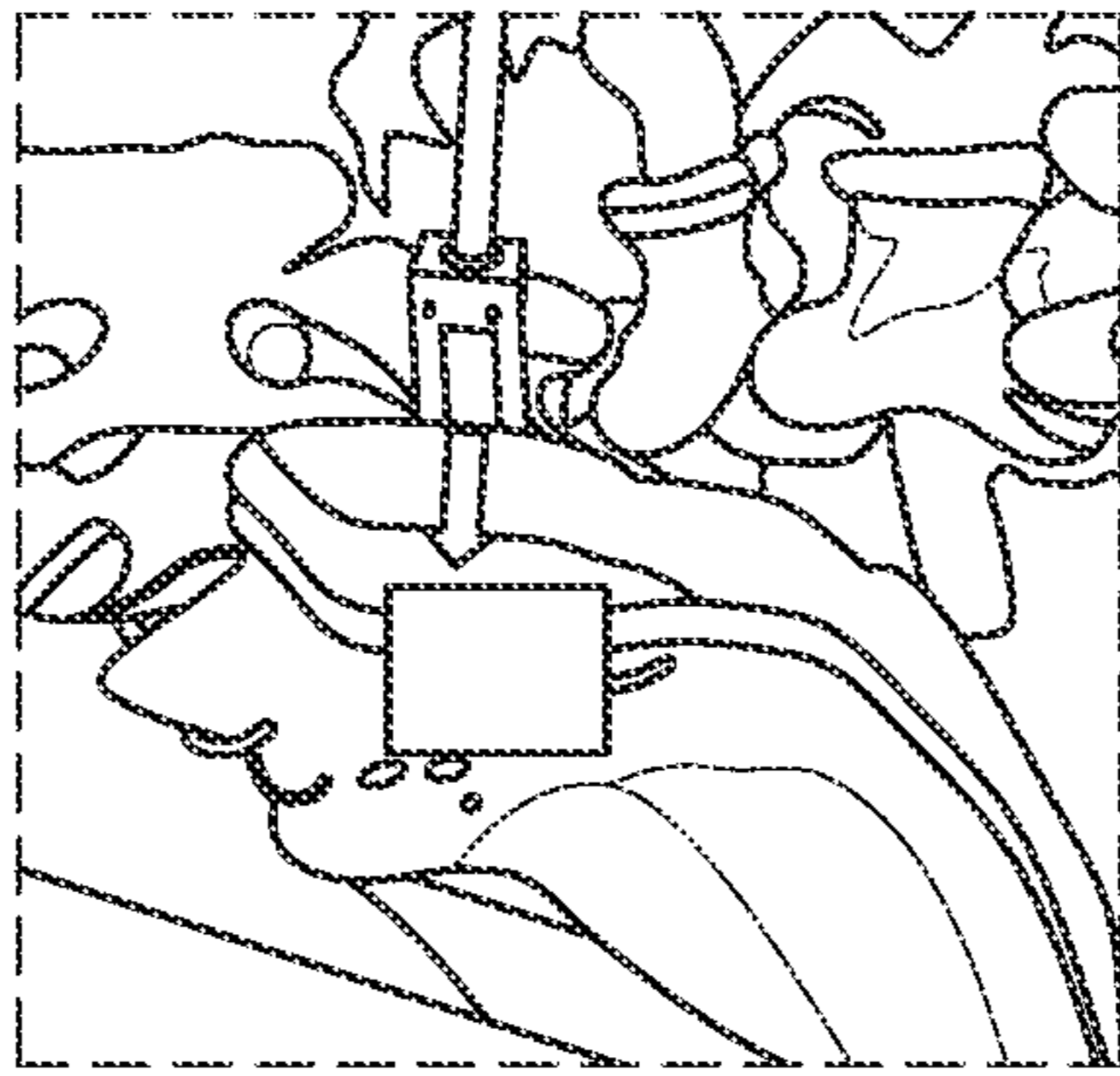


FIG. 25A

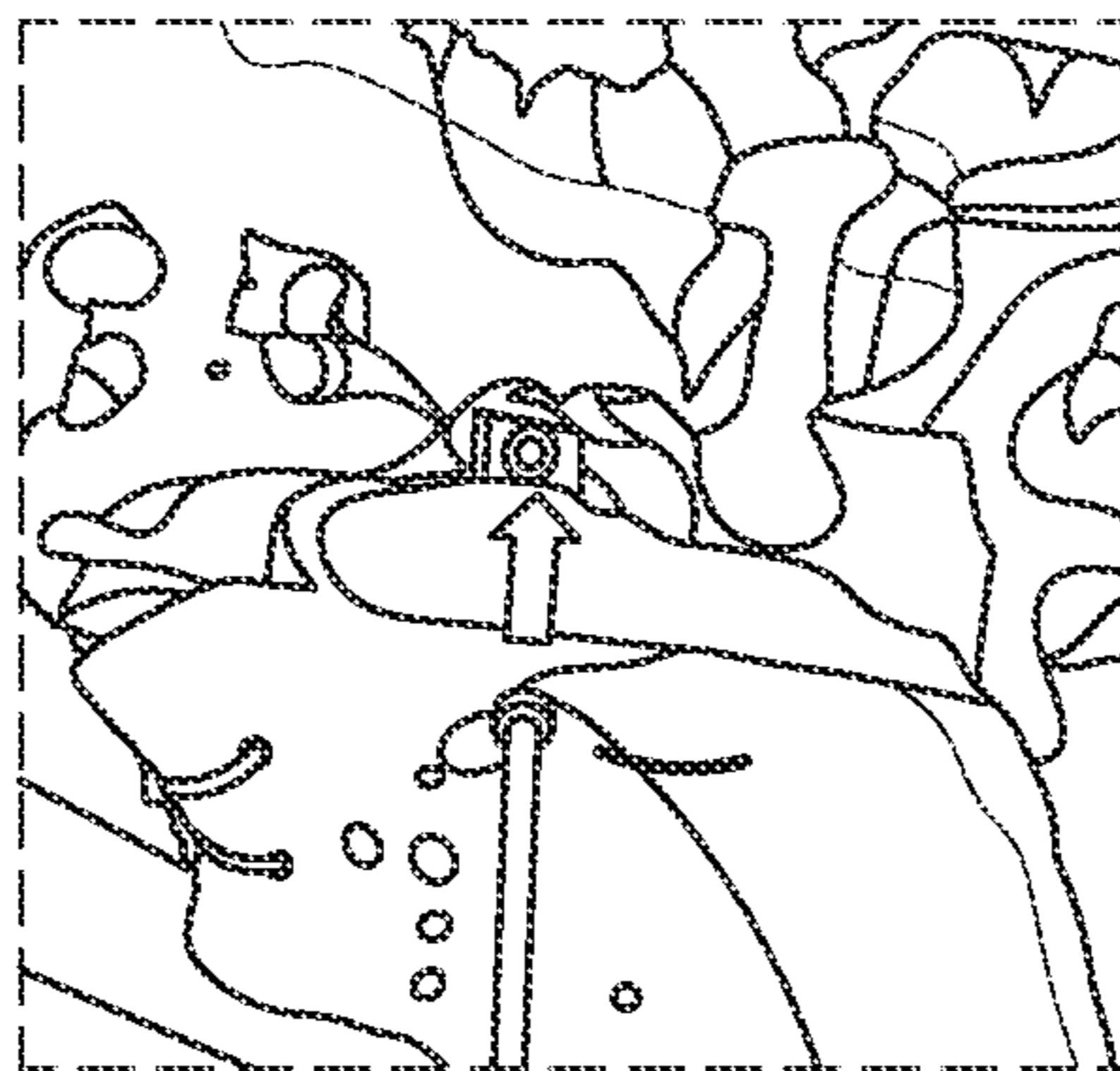


FIG. 25B

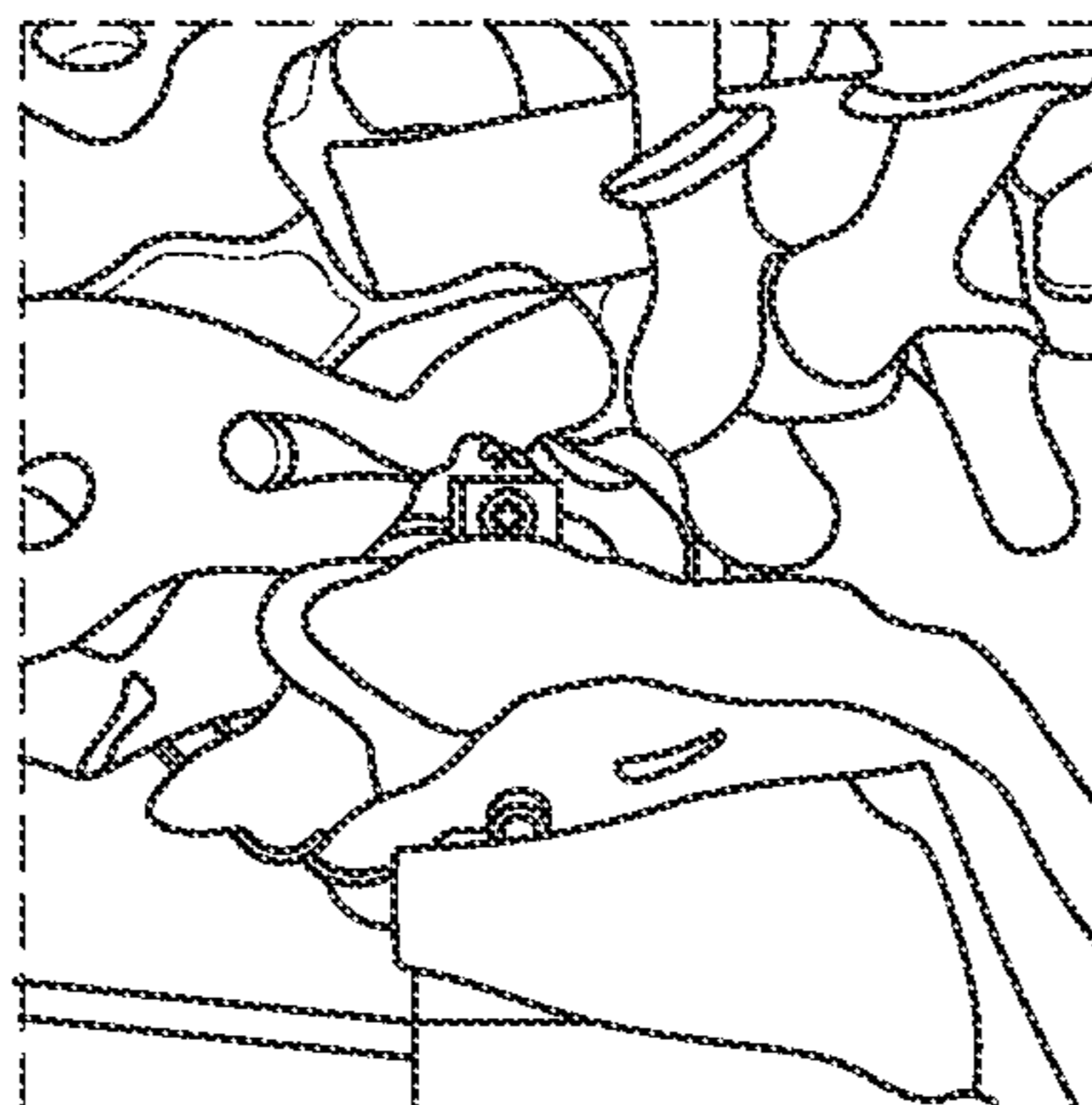


FIG. 25C

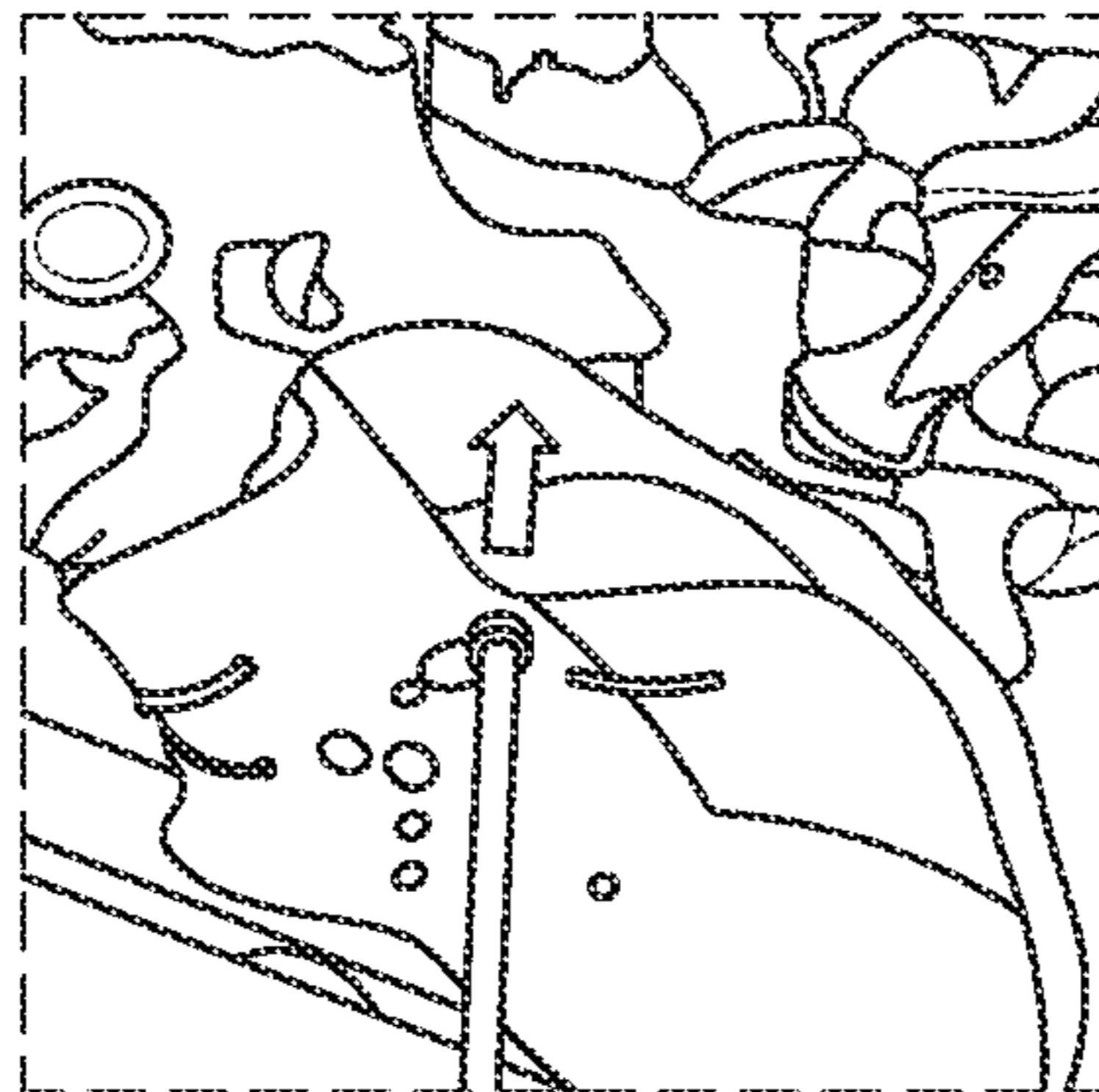


FIG. 26A

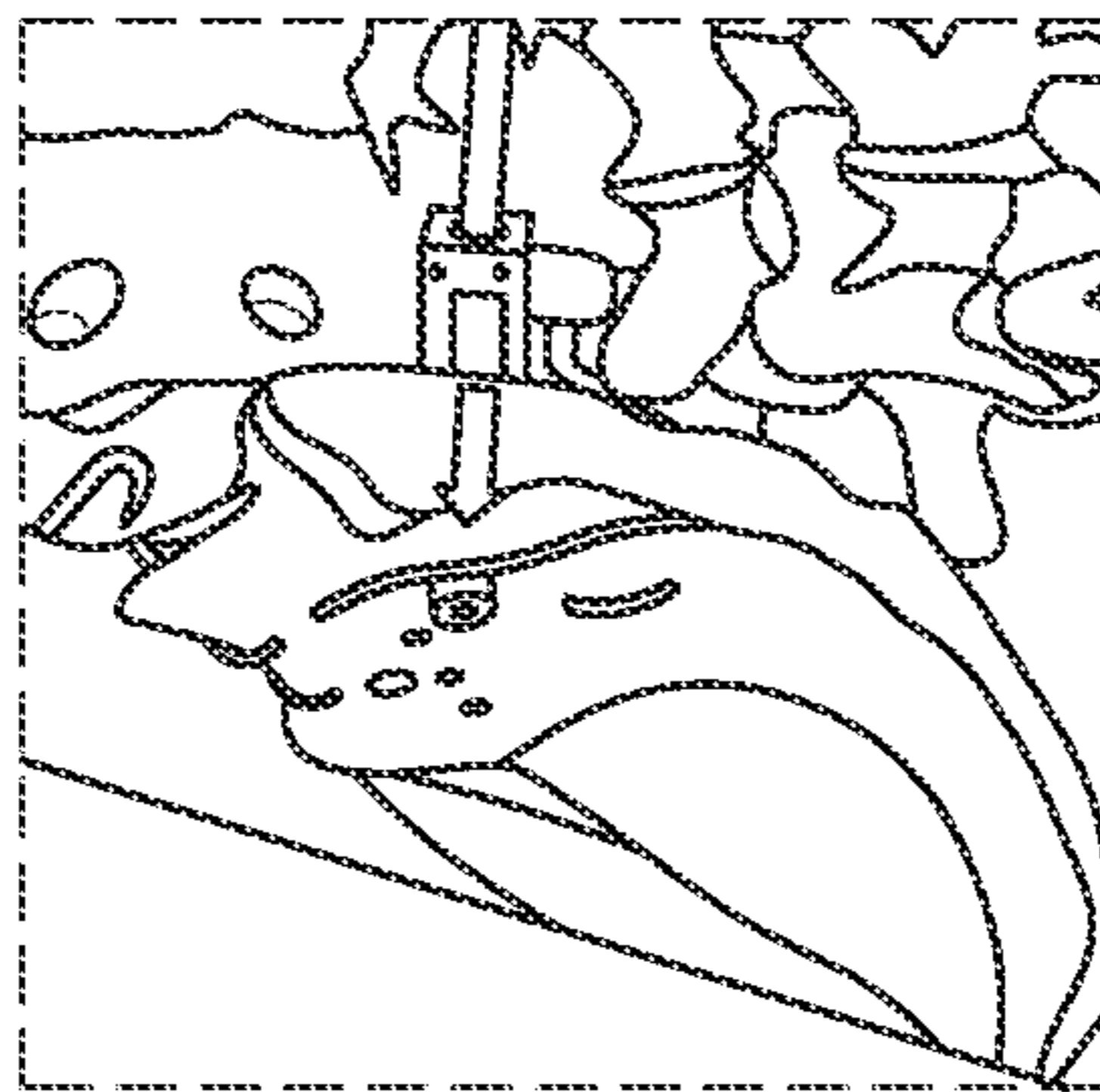


FIG. 26B

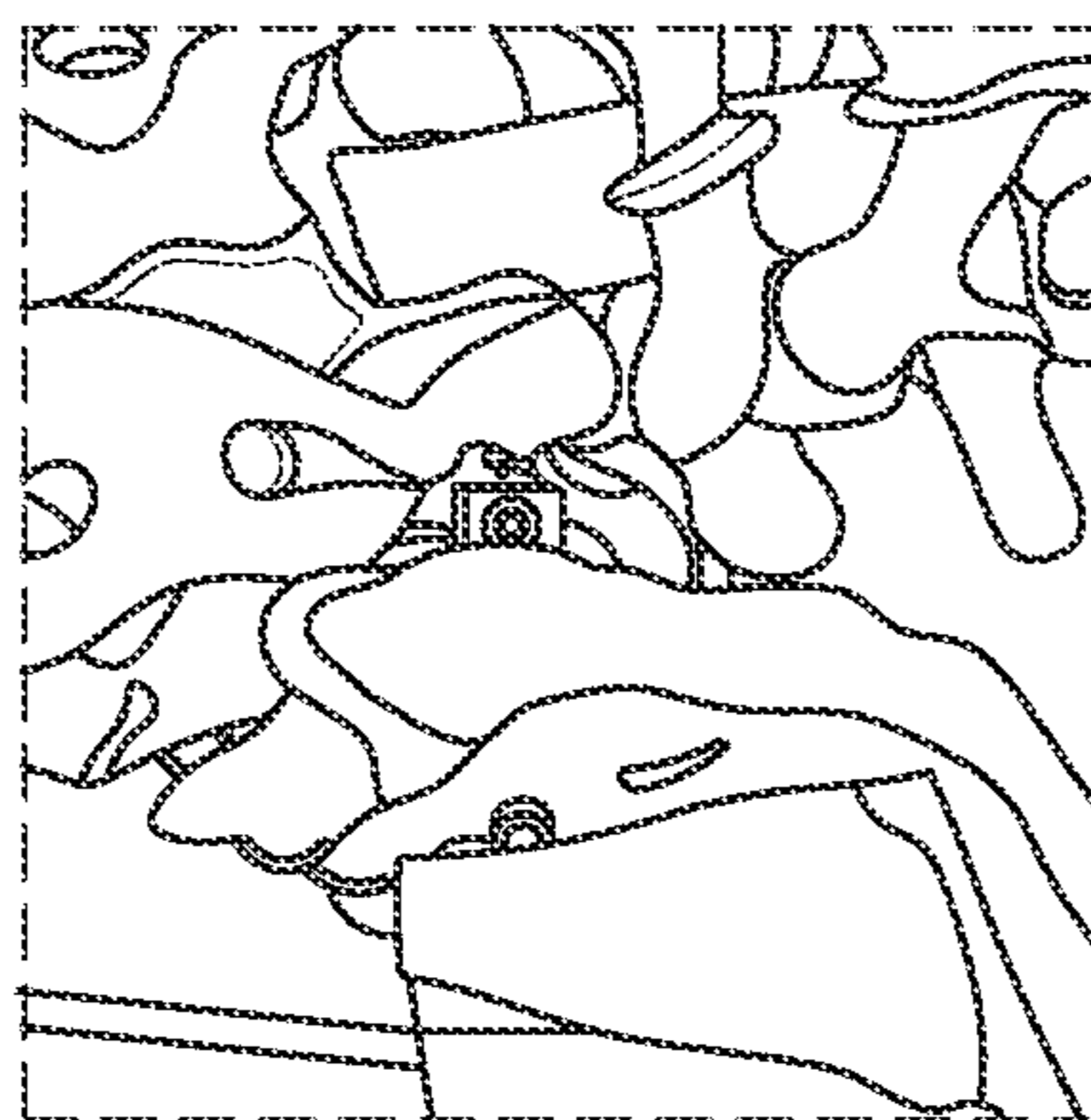
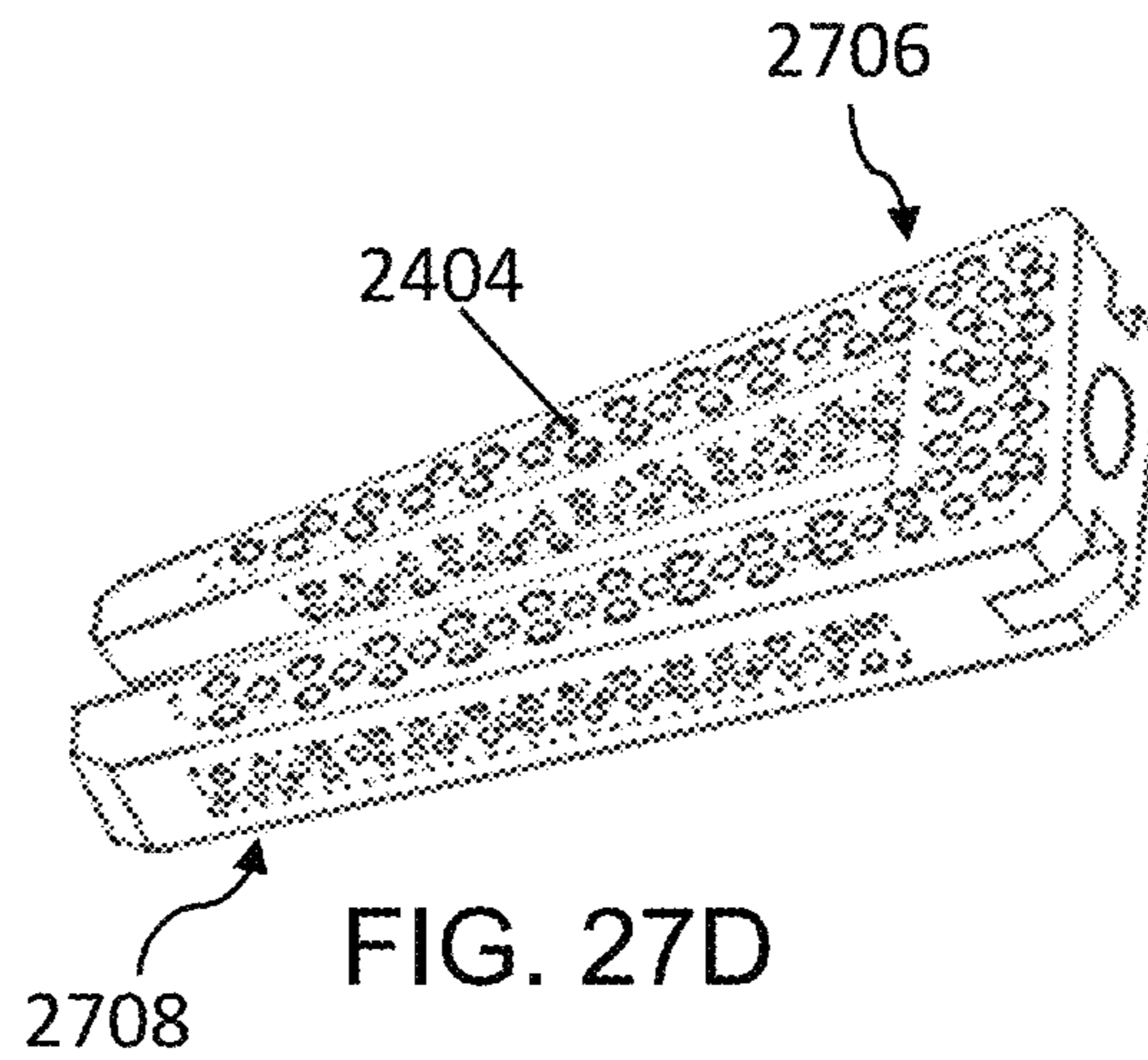
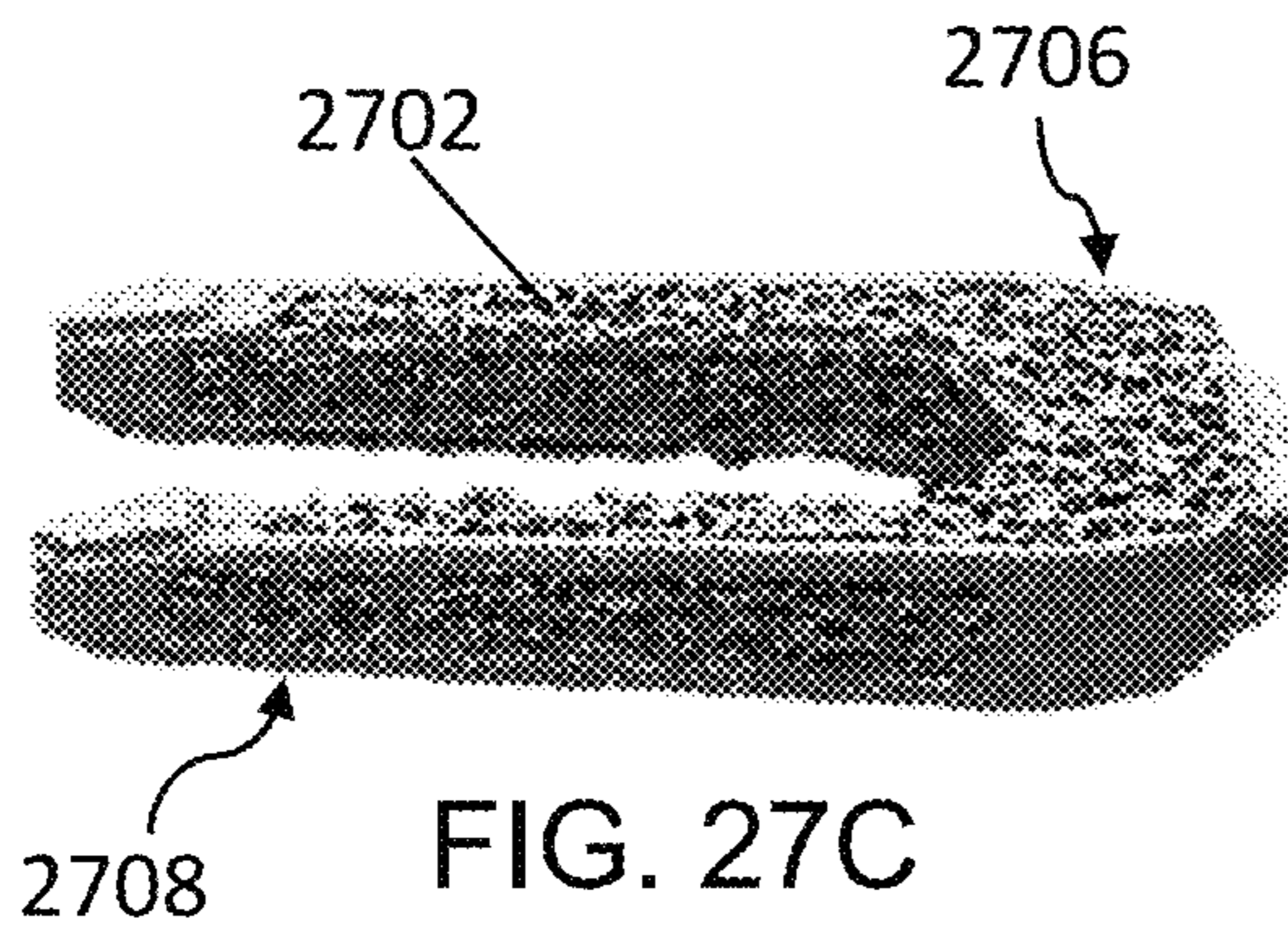
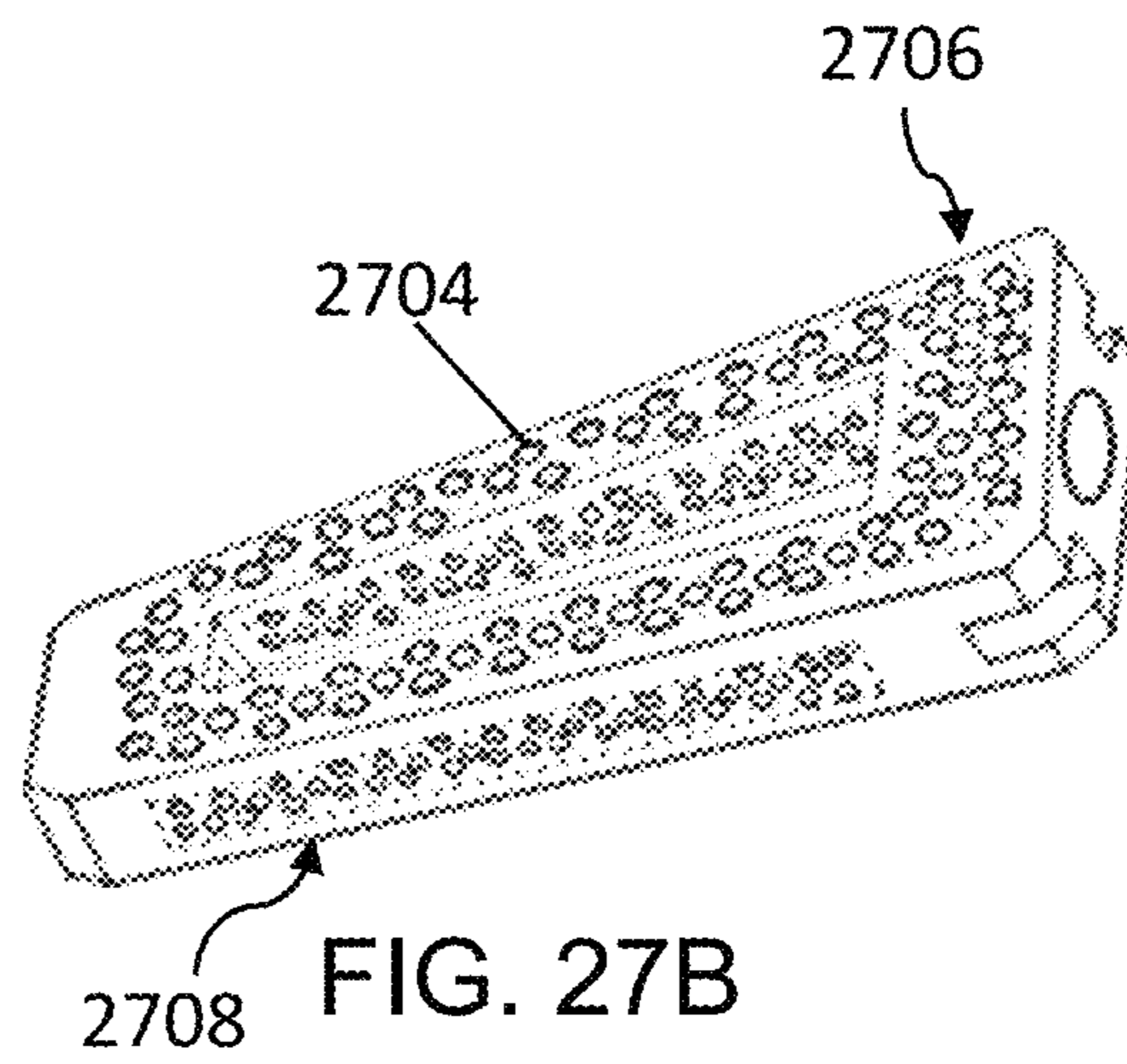
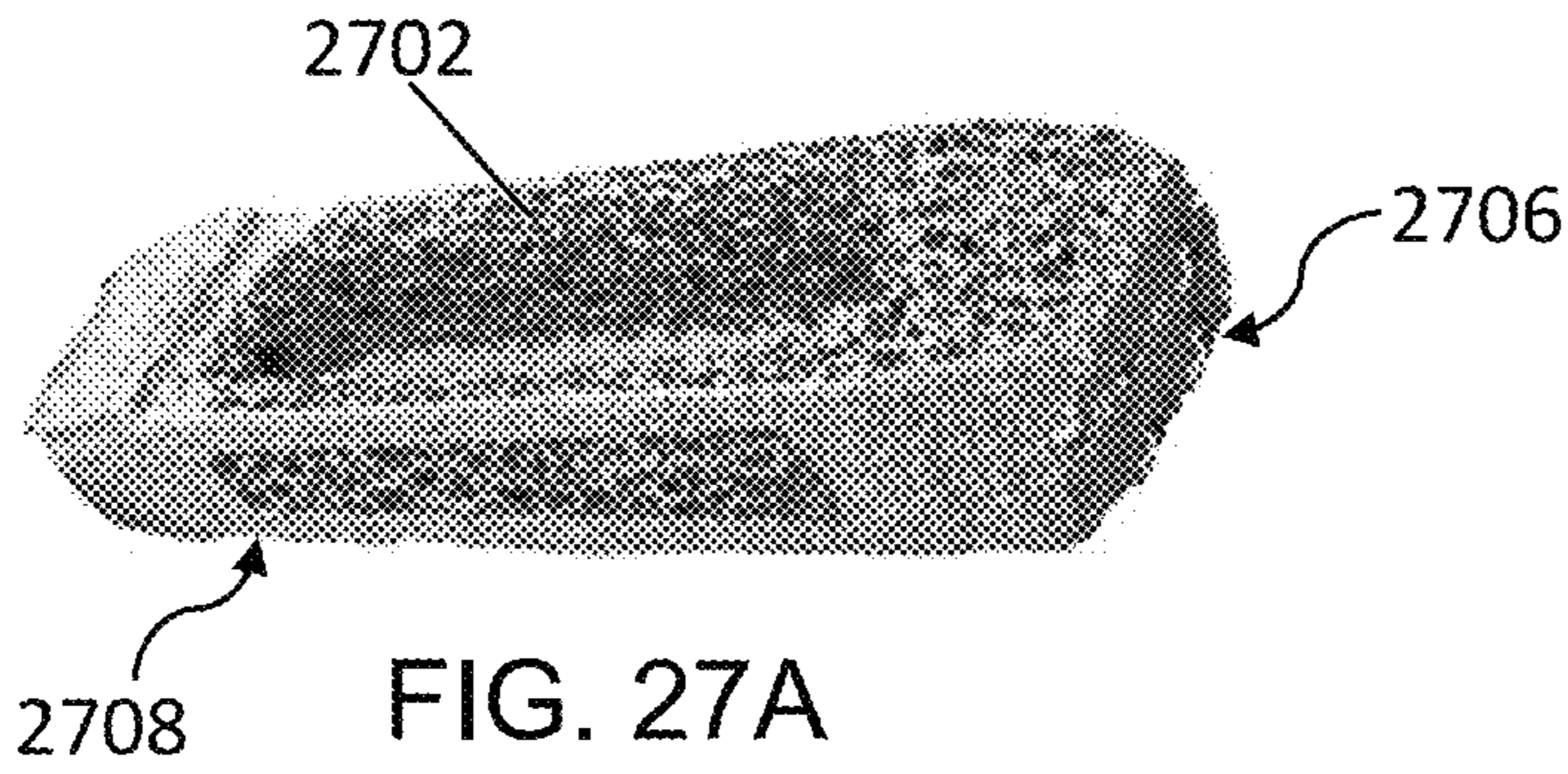


FIG. 26C



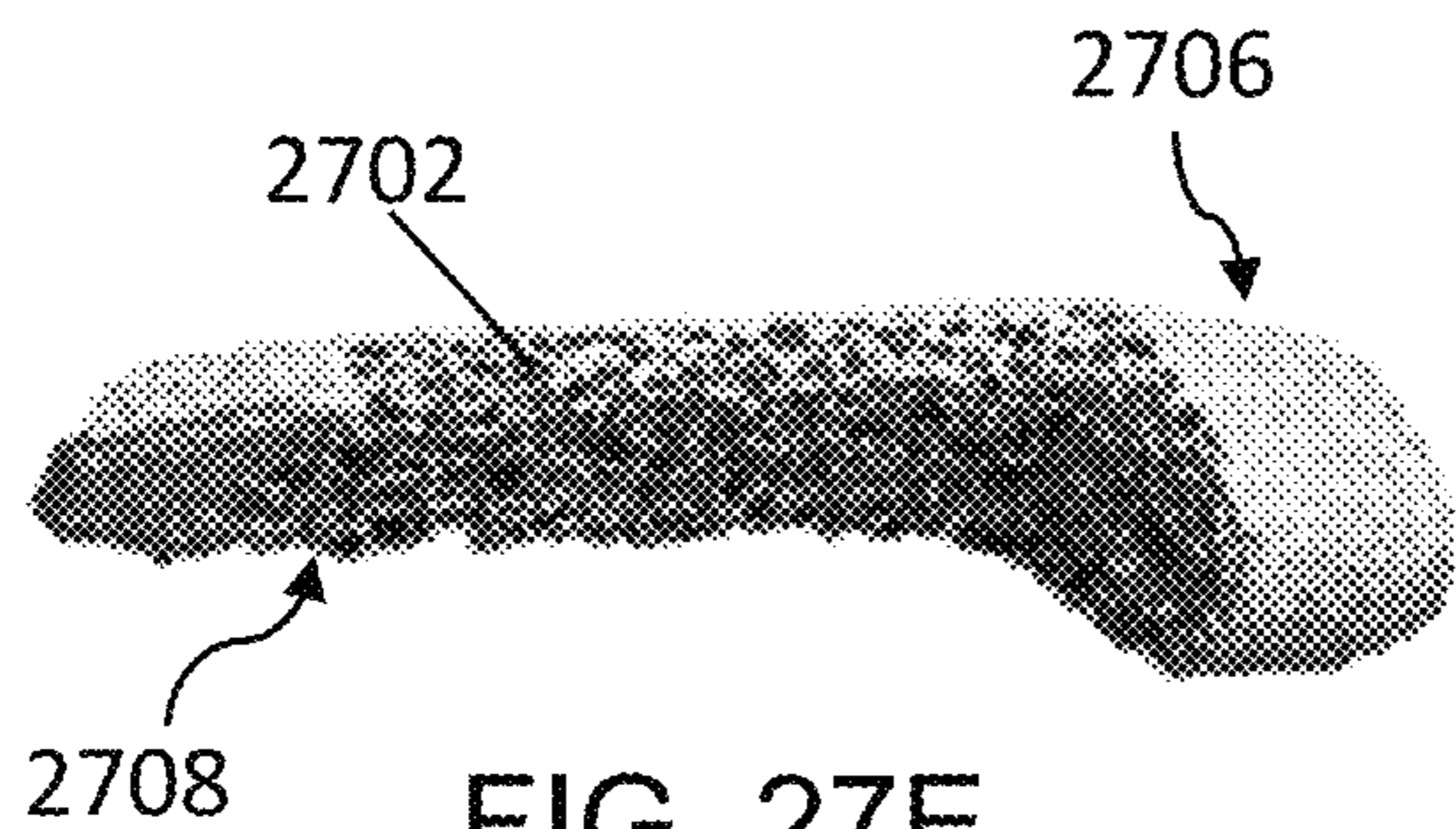


FIG. 27E

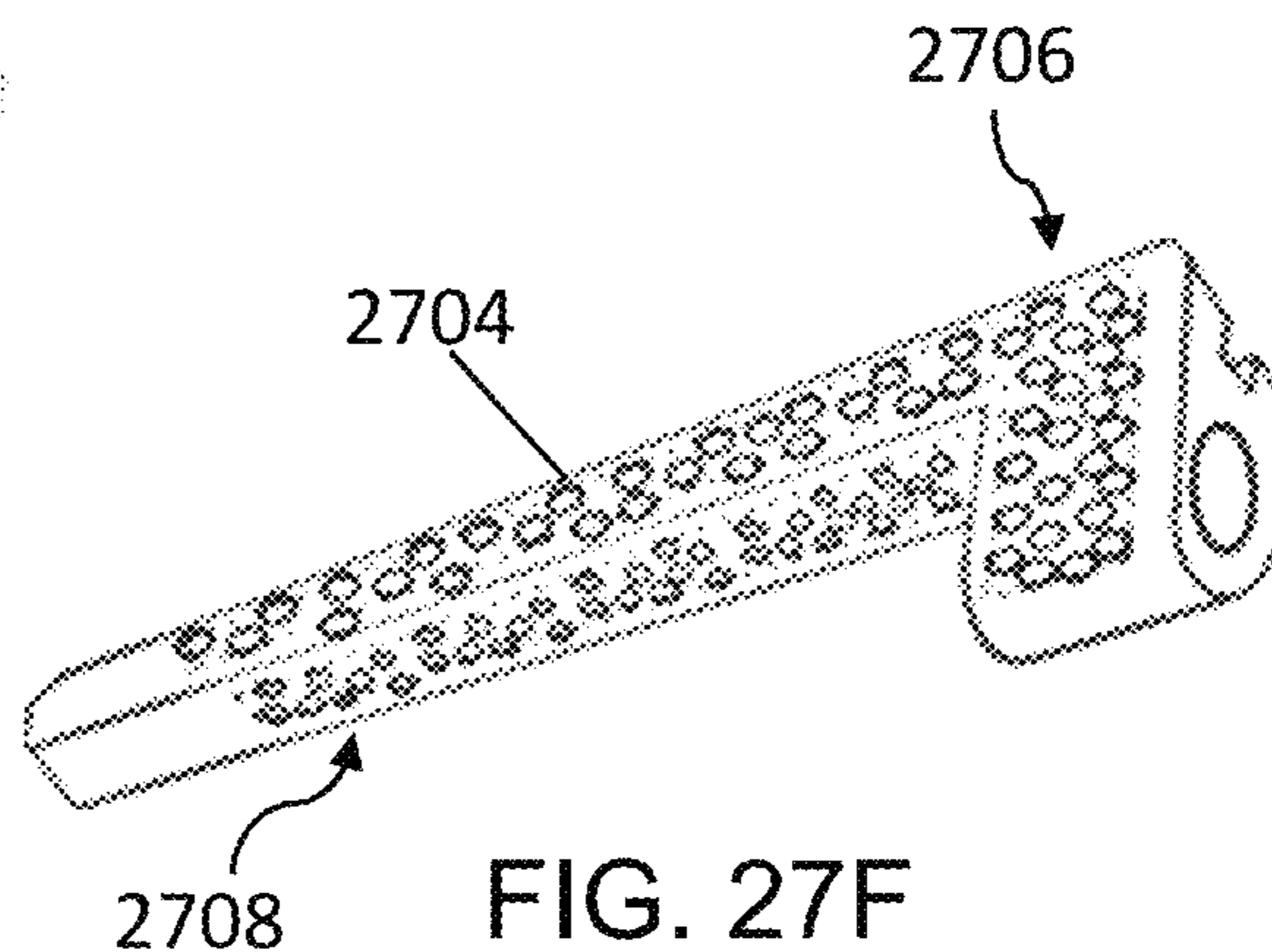


FIG. 27F

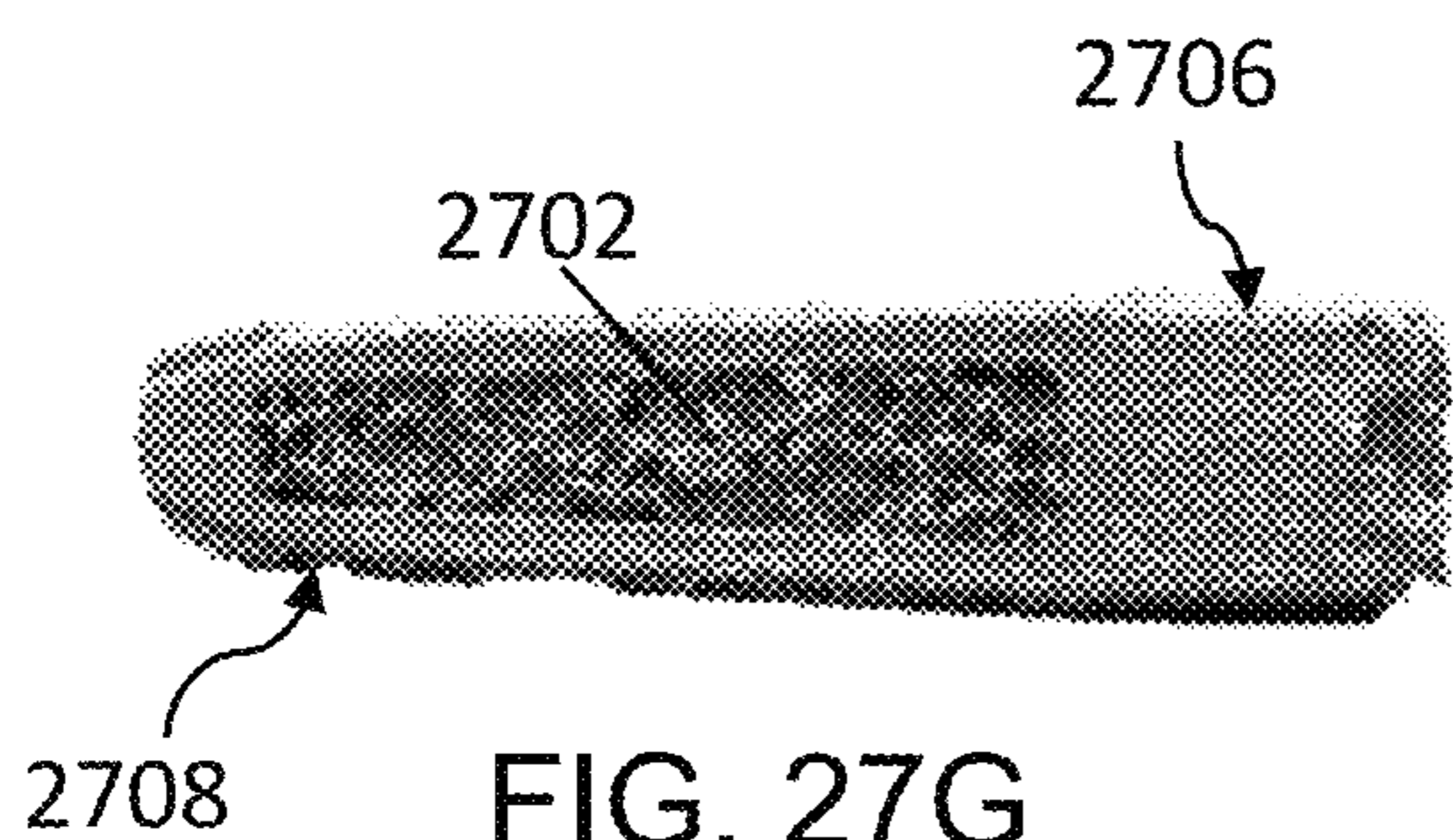


FIG. 27G

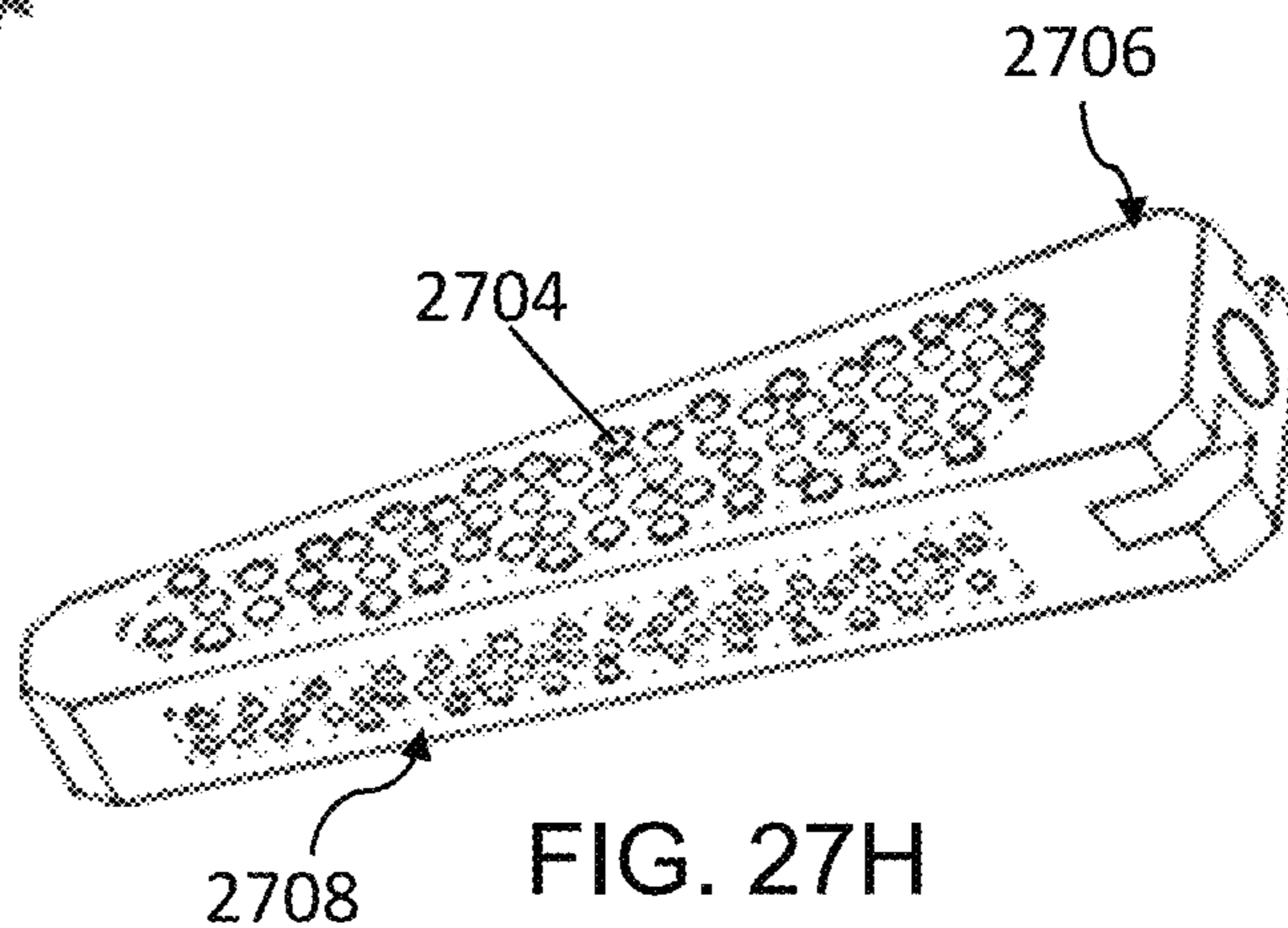


FIG. 27H

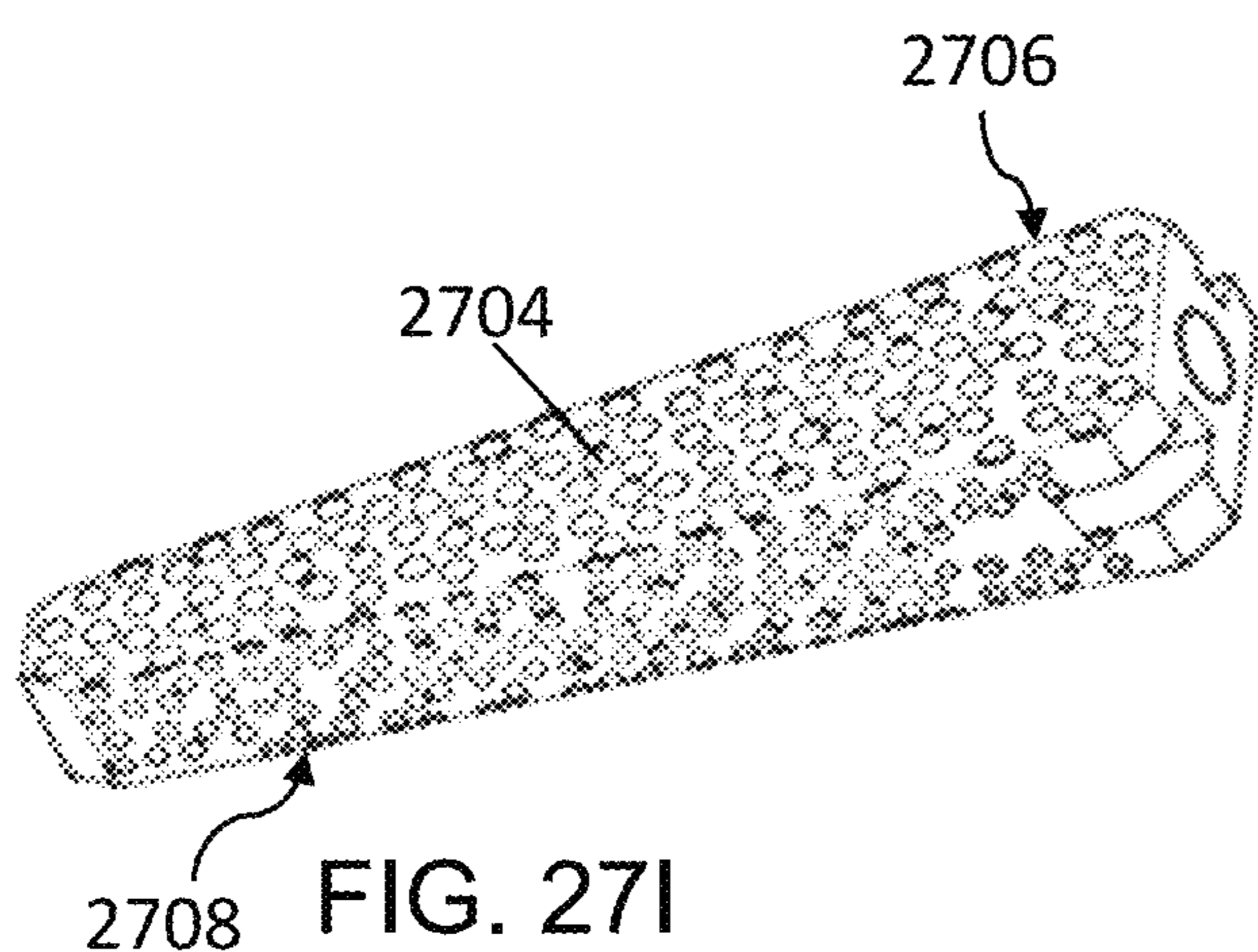


FIG. 27I

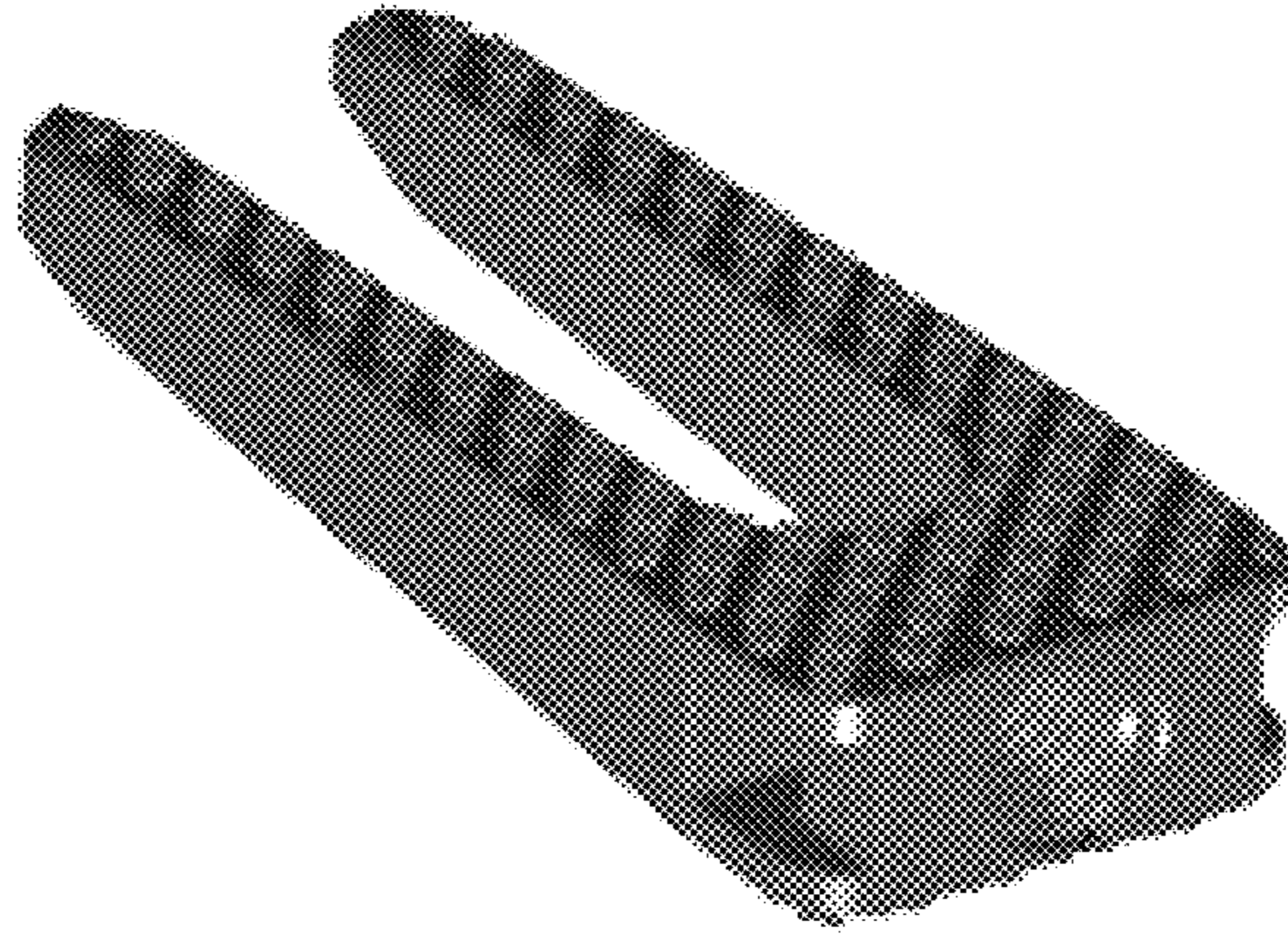


FIG. 28A

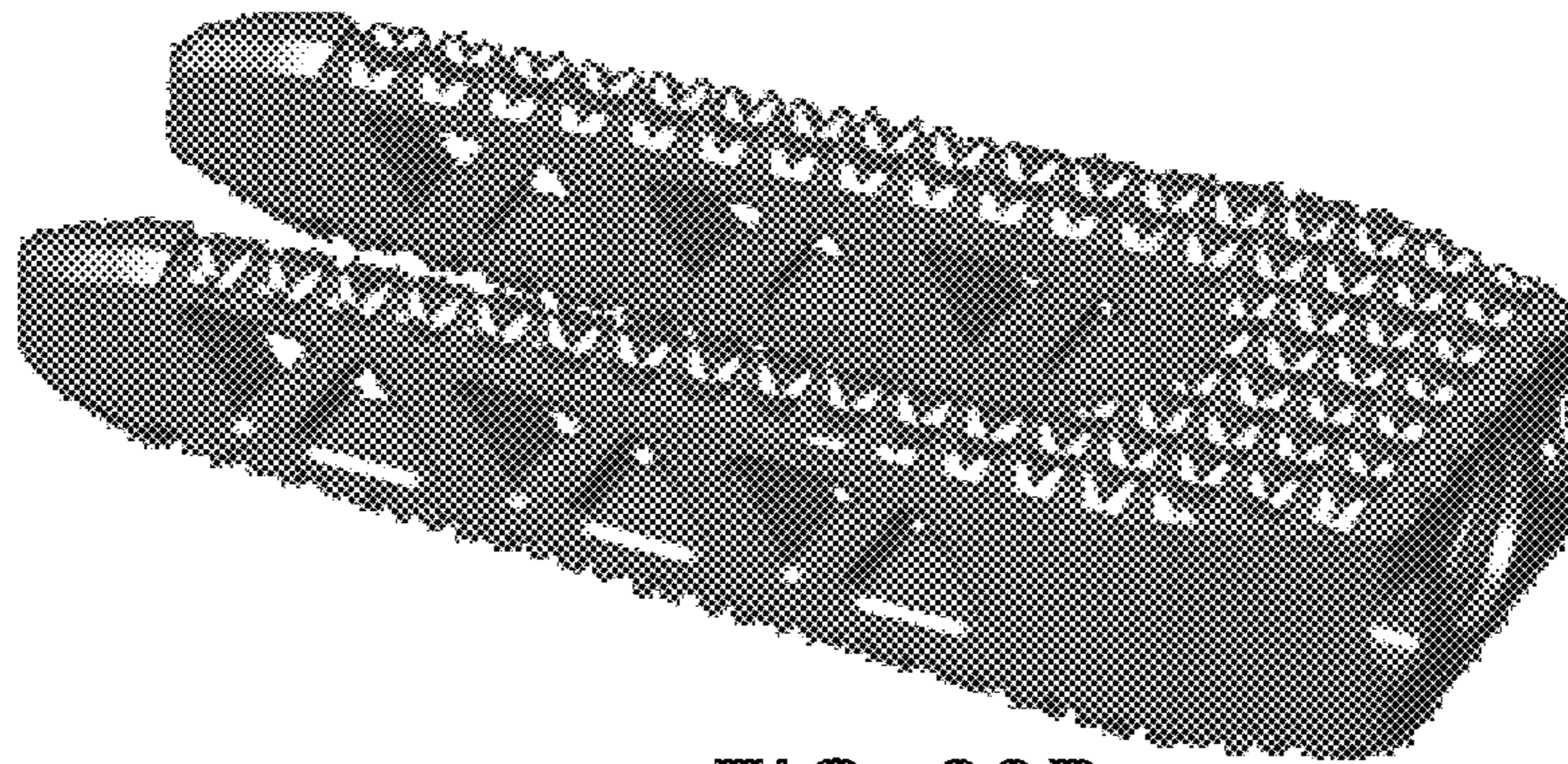


FIG. 28B

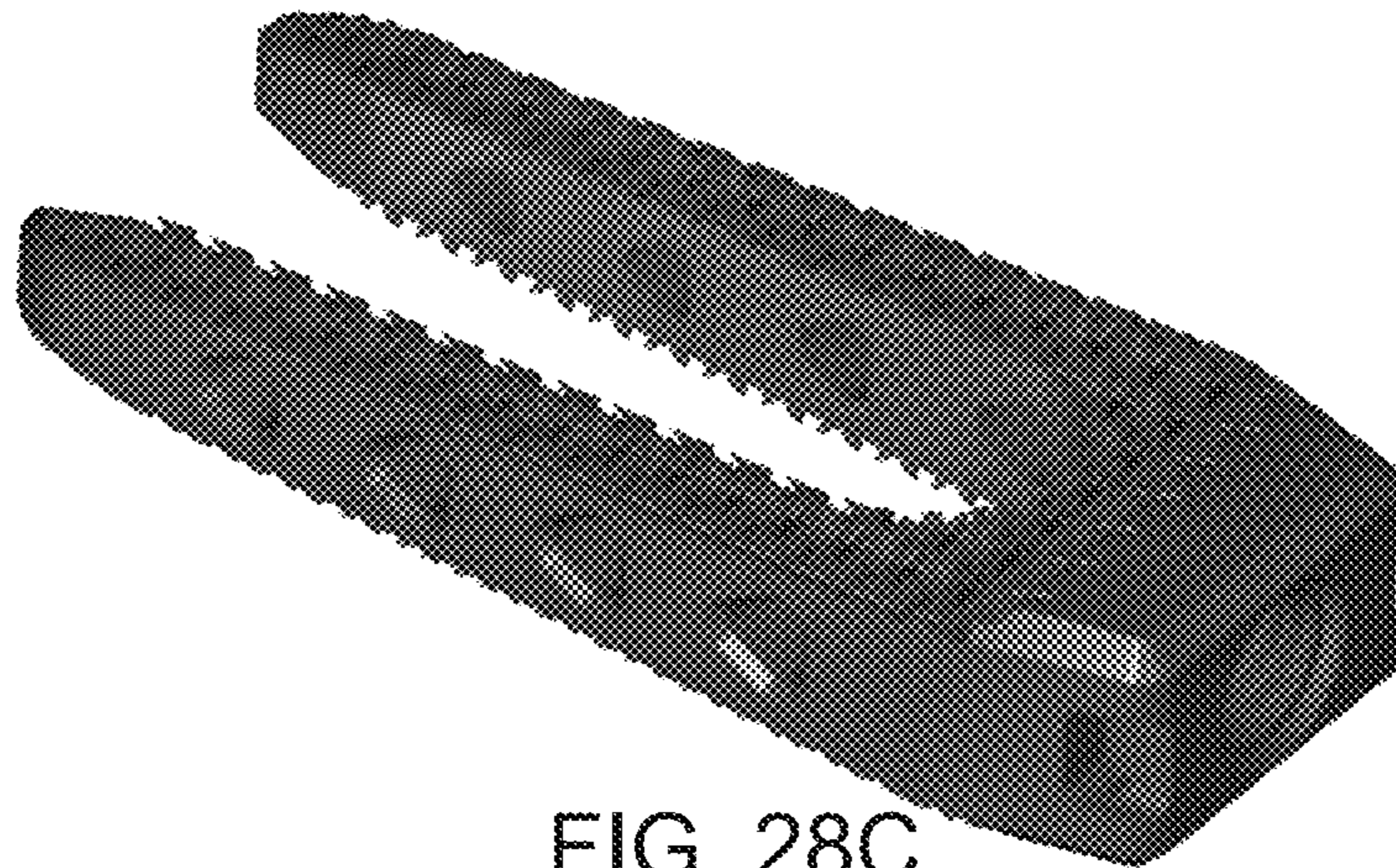


FIG. 28C

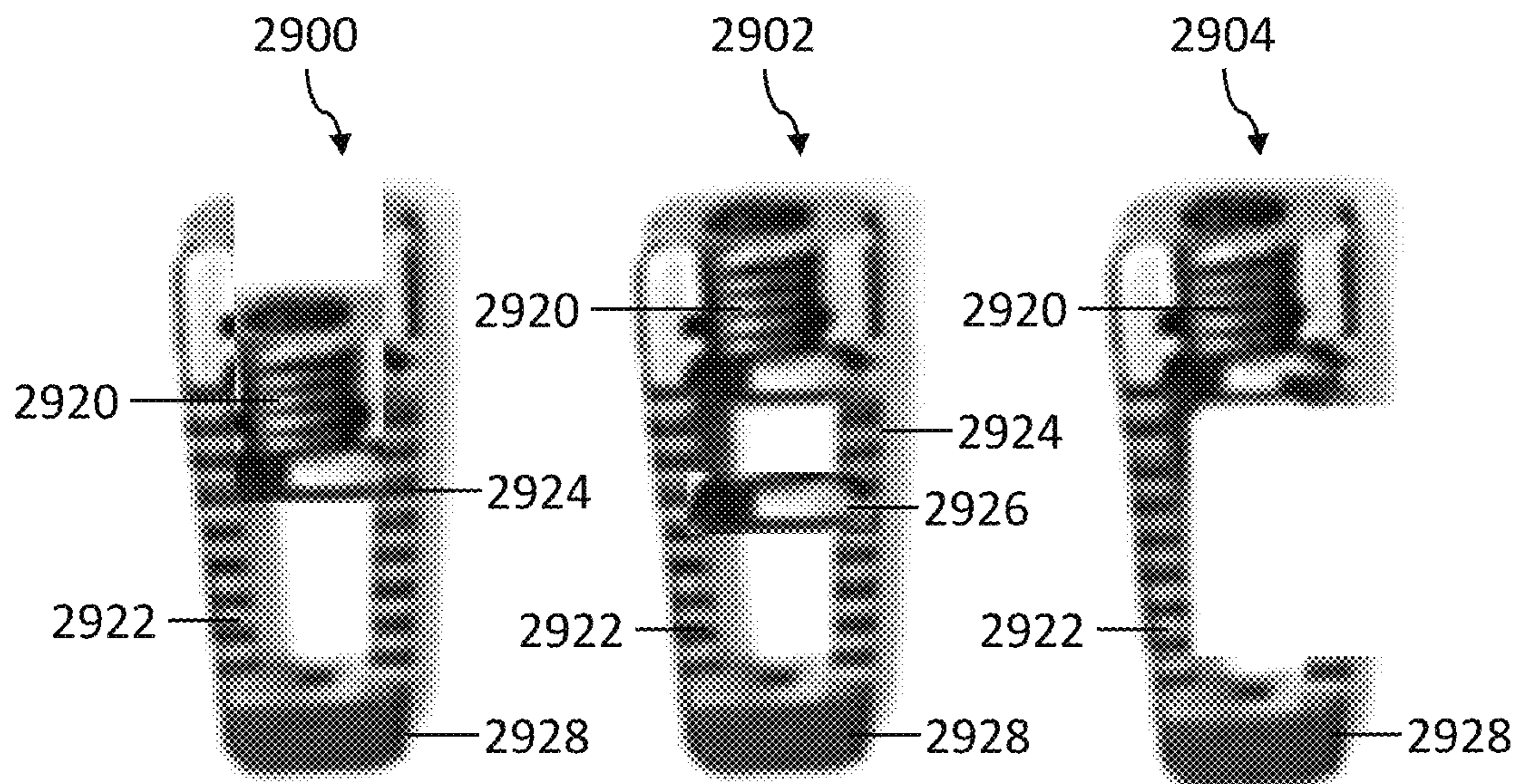


FIG. 29A

FIG. 29B

FIG. 29C

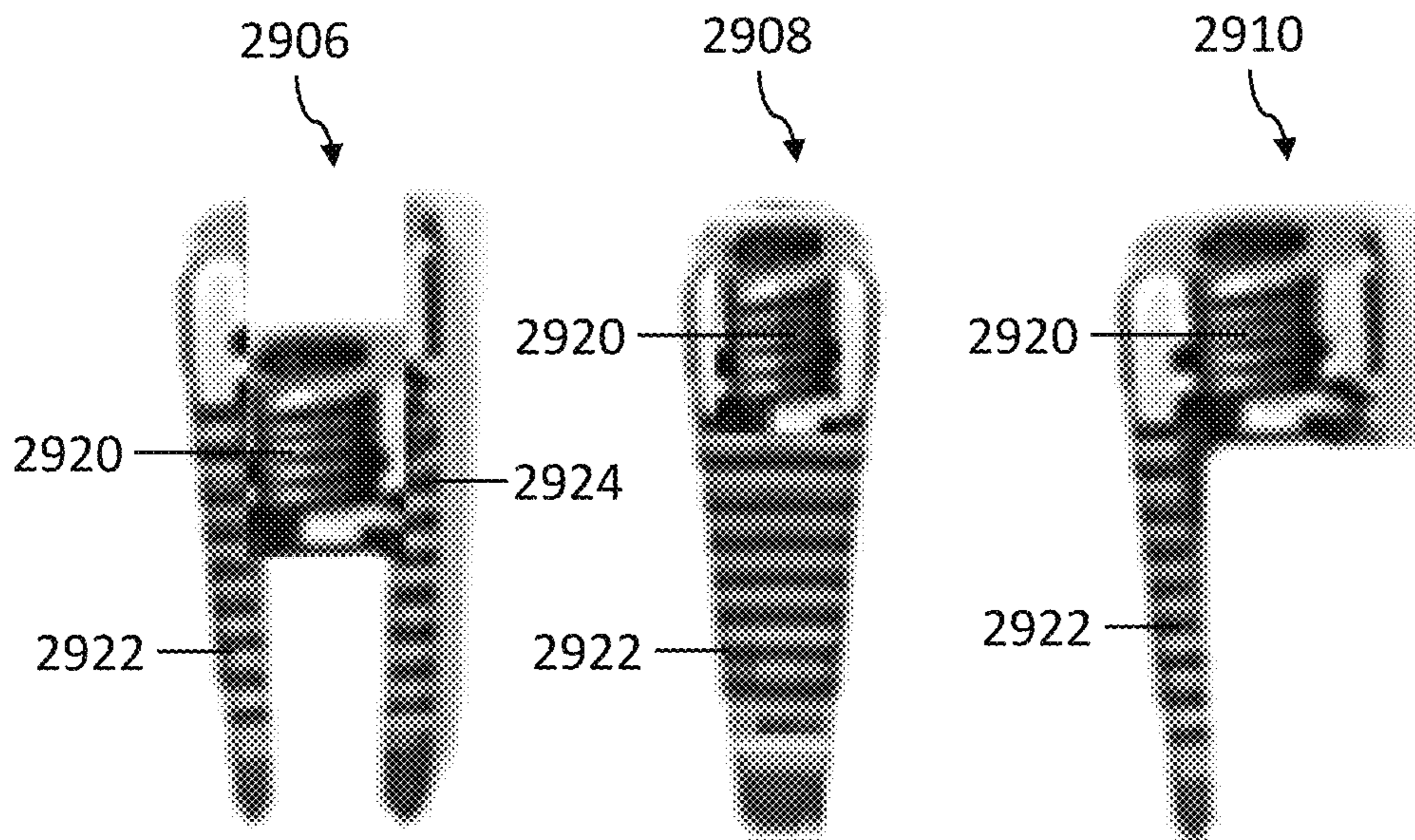


FIG. 29D

FIG. 29E

FIG. 29F

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SACRO-ILIAC (SI) JOINT FIXATION SYSTEM AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 62/809,419 entitled "Wedging Plate," filed Feb. 22, 2019, the disclosure of which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

The present invention relates to methods, devices, and systems for an improved wedging cage within the sacroiliac (SI) joint. More specifically, the improved wedging cage may allow the implantation of the wedging cage before screws are deployed and after screws are deployed.

BACKGROUND OF THE INVENTION

Low back pain (LBP) is exceedingly common in modern society, affecting well over 90% of adults at some point in their lives. Loss of productivity and income combined with medical expenses results in vast expenditures annually in the US related to low back pain. Successful treatment of low back pain demands identifying the pain generator(s), which can be a significant challenge due to the multifactorial nature of this condition.

Traditionally doctors have diagnosed herniated discs and facet joints as primary pain generators, but recently there has been a resurgence in consideration of the SI joint as a low back pain generator. Despite the large number of patients with SI joint pain, treatment options have been limited to conservative care involving physical therapy and joint injections, and if conservative therapy fails, then SI joint fusion surgery is recommended.

However, the current SI fusion implants do not provide flexibility to the doctor during the operative procedure. The doctor must typically choose between screws or cages in an attempt to fuse or fixate the bone surfaces together. Therefore, a need exists to provide an implant system that provides flexibility to use a combination of implants and/or implant components, as well as an implant that can adapt to operative changes to allow both fusion and fixation together.

BRIEF SUMMARY OF THE INVENTION

The following presents a simplified summary of the subject matter in order to provide a basic understanding of some aspects of the subject matter. This summary is not an extensive overview of the subject matter. It is intended to neither identify key or critical elements of the subject matter nor delineate the scope of the subject matter. Its sole purpose is to present some concepts of the subject matter in a simplified form as a prelude to the more detailed description that is presented later.

In accordance with various aspects of the present subject matter, an SI joint fixation system comprises an A-shaped, a B-shaped, a C-shaped, H-shaped, I-shaped, L-shaped, O-shaped, U-shaped, a Y-shaped, and M or W shaped wedging cage and/or any combination thereof. The SI joint fixation system further comprises a screw. The screw includes a fixation screw or an axial screw. The fixation screw is intended to be positioned or deployed perpendicular or substantially perpendicular to the axis of the wedging cage. The axial screw is intended to be positioned or

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deployed parallel or substantially parallel to the axis of the wedging cage or in alignment with the axis of the bore or threaded bore. The SI joint fixation system may further comprise a delivery instrument. The delivery instrument includes a sleeve, an insertion cannula.

The SI joint fixation system comprises an L-shaped or I-shaped wedging cage. The L-shaped and/or I-shaped wedging cage may comprise a base and at least one longitudinal member. The base can include a threaded bore, a top surface and a bottom surface, the threaded bore extending from a top surface through the bottom surface. At least one longitudinal member can extend from a bottom surface of the base. The at least one longitudinal member may extend perpendicularly or substantially perpendicular from the base, the term substantially perpendicular include a variety of angulations, including 0.25 degrees to 10 degrees from neutral. The at least one longitudinal member may include at least a portion of at least one bone contacting surface have a smooth surface or a textured surface, the textured surface may comprise grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof. The SI joint fixation system may further comprise a screw, the screw comprising a head, a shaft and a thread. The screw can be sized and configured to be inserted within the threaded bore. Alternatively, the bottom surface of the base and a portion of the at least one longitudinal member can be sized and configured to receive the screw. The at least one longitudinal member may be positioned adjacent to a circumference of the threaded bore. Alternatively, the at least one longitudinal member may be aligned with a longitudinal axis of the threaded bore.

In another embodiment, the SI joint fixation system comprises a U-shaped wedging cage. The U-shaped wedging cage comprises a base, a first longitudinal member and a second longitudinal member. The base including a threaded bore, a top surface and a bottom surface, the threaded bore extending from a top surface through the bottom surface. The first longitudinal member and the second longitudinal member spaced apart and extending from the bottom surface of the base. The first and/or second longitudinal member extending perpendicularly or substantially perpendicular from the base, the substantially perpendicular includes 0.25 degrees to 10 degrees from neutral. The first and/or second longitudinal member including at least a portion of the at least one bone contacting surface have a smooth surface or a textured surface, the textured surface comprises grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof. The SI joint fixation system may further comprise a screw, the screw comprising a head, a shaft and a thread. The screw is sized and configured to be inserted within the threaded bore and/or the through-hole. Alternatively, the bottom surface of the base and a portion of the first and second longitudinal member is sized and configured to receive the screw.

In another embodiment, the SI joint fixation system comprises an O-shaped wedging cage. The wedging cage comprises a first base, a second base, a first longitudinal member and a second longitudinal member. The first base including a threaded bore, a top surface and a bottom surface, the threaded bore extending from a top surface through the bottom surface. The second base including a through-hole, the through-hole of the second base is aligned with and/or concentrically aligned with the threaded bore of the first base. The first longitudinal member and the second longitudinal member spaced apart and extending between

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the first base and the second base. The first and/or second longitudinal member extending perpendicularly or substantially perpendicular from the base, the substantially perpendicular includes 0.25 degrees to 10 degrees from neutral. The first and/or second longitudinal member including at least a portion of the at least one bone contacting surface have a smooth surface or a textured surface, the textured surface comprises grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof. The SI joint fixation system may further comprise a screw, the screw comprises a head, a shaft and a thread. The screw is sized and configured to be inserted within the threaded bore and/or the through-hole. Alternatively, the bottom surface of the base and a portion of the first and second longitudinal member is sized and configured to receive the screw.

In another embodiment, the SI joint fixation system comprises a H-shaped wedging cage. The H-shaped wedging cage comprises a base, a first longitudinal member and a second longitudinal member. The base including a threaded bore, a top surface and a bottom surface, the threaded bore extending from a top surface through the bottom surface. Each of the first longitudinal member and the second longitudinal member having a longitudinal axis, a first end and a second end. The first longitudinal member and the second longitudinal member spaced apart. The first and/or second longitudinal member extending perpendicularly or substantially perpendicular from the base, the substantially perpendicular includes 0.25 degrees to 10 degrees from neutral. The base positioned between the first end and second end of the first and second longitudinal member. The first and/or second longitudinal member including at least a portion of the at least one bone contacting surface have a smooth surface or a textured surface, the textured surface comprises grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof. The SI joint fixation system may further comprise a screw, the screw comprises a head, a shaft and a thread. The SI joint fixation system may further comprise a screw, the screw comprises a head, a shaft and a thread. The screw is sized and configured to be inserted within the threaded bore and/or the through-hole. Alternatively, the bottom surface of the base and a portion of the first and second longitudinal member is sized and configured to receive the screw.

In another embodiment, the SI joint fixation system comprises an anchored wedging cage. The anchored wedging cage comprises a wedging cage and an anchor assembly. The wedging cage may comprise an A-shaped, a B-shaped, a C-shaped, H-shaped, I-shaped, L-shaped, O-shaped, U-shaped, a Y-shaped, and M or W shaped wedging cage and/or any combination thereof. The wedging cage may comprise at least one base, the at least one base includes a threaded bore. The anchor assembly comprises a plurality of pins and an anchor. The anchor comprises a shaft and at least two blades, the shaft comprising a channel, the channel is disposed around the circumference of the shaft. The channel is sized and configured to receive a portion of the plurality of pins. The anchor assembly is rotatable from an unlocked position to a locked position, the unlocked position has the at least a portion of the anchor mating with a portion of the wedging cage and it allows the wedging cage to move or slide within the SI joint. The locked position rotates the anchor anywhere between 1 degree to 90 degrees away from the portion of the wedging cage and allows the wedging cage to lock into place within the SI joint.

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In another embodiment, the SI joint fixation system comprises a shelled wedging cage and bone growth block. The shell wedging cage comprises a first base, a second base, a first longitudinal member and a second longitudinal member. The first base including a bore, a top surface and a bottom surface, the bore extending from a top surface through the bottom surface. The first longitudinal member and the second longitudinal member spaced apart and extending between the first base and the second base. The first and/or second longitudinal member extending perpendicularly or substantially perpendicular from the first and/or second base, the substantially perpendicular includes 0.25 degrees to 10 degrees from neutral. The first and/or second longitudinal member including at least a portion of the at least one bone contacting surface have a smooth surface or a textured surface, the textured surface comprises grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof. The spacing apart of the first and second longitudinal member is sized and configured to receive the bone growth block.

In another embodiment, the SI joint fixation system comprises a shell wedging cage and a bone growth block. The shell wedging cage comprises a first base and a first longitudinal member, the first longitudinal member extending away from the first base. At least one surface of the first base and the first longitudinal member having a channel. The channel is sized and configured to receive a portion of the both growth block. The SI joint fixation system further comprises a screw, the screw is a fixation screw and/or an axial screw.

In another embodiment the SI joint fixation system may comprise a 3D printed wedging cage. The 3D printed wedging cage may comprise an A-shaped, a B-shaped, a C-shaped, H-shaped, I-shaped, L-shaped, O-shaped, U-shaped, a Y-shaped, and M or W shaped wedging cage and/or any combination thereof. At least a portion of the 3D printed wedging cage comprises porosity. The porosity may include a plurality of connected, interstitial pores uniformly or non-uniformly distributed throughout the entire wedging cage. The interstitial pores may match or substantially match trabecular or cortical patterns. Alternatively, the interstitial pores may have a shape, the shape may comprise a circle, an oval, a regular polygon or irregular polygon shape. The SI joint fixation system further comprises a screw, the screw is a fixation screw and/or an axial screw.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The following description and the annexed drawings set forth in detail certain illustrative aspects of the subject matter. These aspects are indicative, however, of but a few of the various ways in which the principles of the subject matter may be employed and the present subject matter is intended to include all such aspects and their equivalents. Other objects, advantages and novel features of the subject matter will become apparent from the following detailed description of the subject matter when considered in conjunction with the drawings.

FIGS. 1A-1B illustrates one embodiment of the pelvic bones, namely the sacroiliac joint;

FIGS. 2A-2H depict various views of one embodiment of an L-shaped wedging cage system;

FIGS. 3A-3H depict various views of one embodiment of a U-shaped wedging cage system;

FIGS. 4A-4H depict various views of one embodiment of an O-shaped wedging cage system;

FIGS. 5A-5H depict various views of one embodiment of an L-shaped wedging cage;

FIGS. 6A-6H depict various views of one embodiment of a U-shaped wedging cage;

FIGS. 7A-7H depict various views of one embodiment of an O-shaped wedging cage;

FIG. 8 depicts a side view of one embodiment of an I-shaped wedging cage;

FIG. 9 depicts a side view of one embodiment of an H-shaped wedging cage;

FIG. 10A-10C depict various isometric views of different embodiments of surface textures;

FIGS. 11A-11E depict various views of one embodiment of a screw;

FIGS. 12A-12E depict various views of an alternate embodiment of a screw;

FIGS. 13A-13E depict various views of an alternative embodiment of a screw;

FIGS. 14A-14E depict various views of one embodiment of a collar;

FIGS. 15A-15D depict isometric views of different embodiments of a shell wedging cage system;

FIGS. 16A-16G depict various views of one embodiment of an anchored wedging cage system;

FIGS. 17A-17E depict various views of one embodiment of an anchor assembly;

FIGS. 18A-18B depict top view of one embodiment of the locked and unlocked position of the anchored wedging cage system;

FIGS. 19A-19D depict front views of various embodiments of the axial positioning of the anchor assembly within the anchored wedging cage system;

FIGS. 20A-20C depict various views of one embodiment of an axial threaded wedging cage system comprising a delivery instrument;

FIG. 20D depicts an exploded view of the axial threaded wedging cage system of FIGS. 20A-20C comprising a delivery instrument;

FIGS. 21A-21D depict various views of one embodiment of a sleeve;

FIGS. 22A-22D depict various views of one embodiment of an insertion cannula;

FIGS. 23A-23D depict various views of one embodiment of an axial threaded anchor wedging cage;

FIGS. 24A-24D depict various views of one embodiment of an axial threaded anchor wedging cage of FIGS. 23A-23D

FIGS. 25A-25C illustrates one embodiment of a method to implant the SI joint wedging cage system;

FIGS. 26A-26C illustrates an alternate embodiment of a method to implant the SI joint wedging cage system;

FIGS. 27A-27I depicts isometric views of different embodiments of 3D printed wedging cages;

FIGS. 28A-28C depict isometric views of different embodiments of wedging cages openings; and

FIGS. 29A-29F depict front views of the different embodiments of wedging cages.

DETAILED DESCRIPTION OF THE INVENTION

The disclosure and the various features and advantageous details thereof are explained more fully with reference to the non-limiting embodiments and examples that are described and/or illustrated in the accompanying drawings and detailed in the following description. It should be noted that

the features illustrated in the drawings are not necessarily drawn to scale, and features of one embodiment may be employed with other embodiments as the skilled artisan would recognize, even if not explicitly stated herein. Descriptions of well-known components and processing techniques may be omitted so as to not unnecessarily obscure the embodiments of the disclosure. The examples used herein are intended merely to facilitate an understanding of ways in which the disclosure may be practiced and to further enable those of skill in the art to practice the embodiments of the disclosure. Accordingly, the examples and embodiments herein should not be construed as limiting the scope of the disclosure. Moreover, it is noted that like reference numerals represent similar parts throughout the several views of the drawings.

The terms “including,” “comprising” and variations thereof, as used in this disclosure, mean “including, but not limited to,” unless expressly specified otherwise. The terms “a,” “an,” and “the,” as used in this disclosure, mean “one or more,” unless expressly specified otherwise.

Devices and/or device components that are disclosed in communication with each other need not necessarily be in continuous communication with each other, unless expressly specified otherwise. In addition, devices that are in direct contact with each other may contact each other directly or indirectly through one or more intermediary articles or devices. The device(s) disclosed herein may be made of a material such as silicon nitride, which may alternatively be combined, in various embodiments, with other materials such as, for example, a polymer, a metal, an alloy, or the like. For instance, the device(s) may comprise silicon nitride, alone or in combination with a Polyether Ether Ketone (PEEK), titanium, a titanium alloy, or the like, or various combinations of the foregoing. The material may be formed by a process such as, for example, an active reductive process of a metal (e.g., titanium or titanium alloy) to increase the amount of nanoscaled texture to device surface(s), so as to increase promotion of bone growth and fusion.

Although process steps, method steps, or the like, may be described in a sequential order, such processes and methods may be configured in alternate orders. In other words, any sequence or order of steps that may be described does not necessarily indicate a requirement that the steps be performed in that order. The steps of the processes or methods described herein may be performed in any order practical. Further, some steps may be performed simultaneously.

When a single device or article is described herein, it will be readily apparent that more than one device or article may be used in place of a single device or article. Similarly, where more than one device or article is described herein, it will be readily apparent that a single device or article may be used in place of the more than one device or article. The functionality or the features of a device or article may be alternatively embodied by one or more other devices or articles which are not explicitly described as having such functionality or features.

Certain exemplary embodiments will now be described to provide an overall understanding of the principles of the structure, function, manufacture, and use of the devices and methods disclosed herein. One or more examples of these embodiments are illustrated in the accompanying drawings. Those of ordinary skill in the art will understand that the devices and methods specifically described herein and illustrated in the accompanying drawings are non-limiting exemplary embodiments and that the scope of the present invention is defined solely by the claims. The features illustrated or described in connection with one exemplary embodiment

may be combined with the features of other embodiments. Such modifications and variations are intended to be included within the scope of the present invention.

The present invention provides various devices, systems and methods for treating various anatomical structures of the spine and/or sacrum and/or other areas of human and/or animal bodies. While the disclosed embodiments may be particularly well suited for use during surgical procedures for the repair, fixation and/or support of sacral anatomy and the spine, it should be understood that various other anatomical locations of the body may benefit from various features of the present invention. Various surgical methods for preparing anatomical surfaces and/or for implanting or placement of the various devices and/or components described herein are also described, including the insertion and placement of implants between adjacent structures and/or portions thereof of the spine and/or sacrum, as well as within bones and/or between other joint surfaces.

In accordance with another aspect of the present subject matter, various methods for manufacturing devices and/or components thereof, as set forth within any of the details described with the present application, are provided.

If desired, implants can be constructed from a variety of modular components, including modular components comprising different materials. If desired, such modular components could be provided in a kit form for selection and/or assembly in a surgical theatre and/or in situ during a surgical procedure. If desired, various components may be removable and replaceable.

The present subject matter will now be described with reference to the drawings, wherein like reference numerals are used to refer to like elements throughout. It is to be appreciated that the various drawings are not necessarily drawn to scale from one figure to another nor inside a given figure, and in particular that the size of the components may be arbitrarily drawn for facilitating the understanding of the drawings. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present subject matter. It may be evident, however, that the present subject matter can be practiced without these specific details. Additionally, other embodiments of the subject matter are possible and the subject matter is capable of being practiced and carried out in ways other than as described. The terminology and phraseology used in describing the subject matter is employed for the purpose of promoting an understanding of the subject matter and should not be taken as limiting.

In accordance with various aspects of the present subject matter, a SI joint fixation system is disclosed which help reduce the symptoms caused by sacroiliac dysfunction, and provide the flexibility to surgeons during the operative procedure—in which surgeons are typically currently limited to choose between fusion or fixation. The SI joint wedging cage system addresses a variety of concerns by allowing the surgeon to adapt hybrid strategies such as fixation alone (screws or similar hardware), fusing alone, and/or fixation plus fusion together. The fixation plus fusion together is advantageous because the SI joint is acutely stabilized allowing long-term immobility as a result of adherence to the transfixing implant and the bone growth within the SI joint itself.

FIGS. 1A-1B illustrates one embodiment of the pelvic bones **100**, namely the sacroiliac joint **106**. The sacroiliac joint (SI) **106**, often referred to as the “SI joint” is the space located between the sacrum bone **102** and the ilium **104**. There are two SI joints **106**—one on either side of the sacrum **102**. The sacrum **102** locks in between the two ilia

104 (or innominates) by acting as a wedge. The top of the sacrum **102** is wider than the bottom, which enables a snug fit between the bones at that level, providing a “wedge-like” shape. The sacrum **102** and the ilium **104** are further held in place by ligaments **110**, which these ligaments **110** help the sacrum support the weight of the spine and head. The space at the top of the sacrum **102** and the ilium **104** is the articular cavity **108**. The articular cavity **108** allows particular SI joint implants to be inserted after the smooth articular cartilage is removed.

SI Joint Fixation Systems

FIGS. 2A-2H depict various views of one embodiment of an L-shaped wedging cage system **200**. The L-shaped wedging cage system **200** comprises a wedging cage **204** and a fixation screw **202**. The wedging cage **204** comprises a base **208** and at least one longitudinal member **210**. The base **208** including a threaded bore **206**, a top surface **212** and a bottom surface **214**, the threaded bore **206** extending from a top surface **212** through the bottom surface **214**. The at least one longitudinal member **210** extending from the base **208** and/or the bottom surface **214** of the base **208**. The at least one longitudinal member **210** extending perpendicularly or substantially perpendicular from the base **208**, the substantially perpendicular includes 0.25 degrees to 10 degrees from neutral. The at least one longitudinal member **210** including at least one bone contacting surface **216**, a least a portion of the at least one bone contacting surface **216** having a smooth surface or a textured surface, the textured surface comprises grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof. The SI joint fixation system may further comprise a fixation screw **202**, the fixation screw **202** comprises a head **218**, a shaft **220** and a thread **222**. The fixation screw **202** may further comprise a collar. At least a portion of the fixation screw **202** contacts or mates to a portion of the bottom surface **214** of the base **208** and at least a portion of the at least one longitudinal member **210**. At least a portion of the at least one longitudinal member **210** may be positioned adjacent to a circumference of the threaded bore **206** and/or the at least one longitudinal member may be positioned offset from the threaded bore **206** to provide for the “L-shape” wedging cage.

FIGS. 3A-3H depict various views of one embodiment of a U-shaped wedging cage system **300**. The SI joint fixation system **300** comprises a U-shaped wedging cage **304** and a fixation screw **302**. The U-shaped wedging cage **304** comprises a base **308**, a first longitudinal member **310** and a second longitudinal member **312**. The base **308** including a threaded bore **306**, a top surface **316** and a bottom surface **314**, the threaded bore **306** extending from a top surface **316** through the bottom surface **314**. The first longitudinal member **310** and the second longitudinal member **312** spaced apart and extending from the bottom surface **314** of the base **308**. The first **310** and/or second **312** longitudinal member extending perpendicularly or substantially perpendicular from the base, the substantially perpendicular includes 0.25 degrees to 10 degrees from neutral. The first **310** and/or second **312** longitudinal member including at least a portion of the at least one bone contacting surface **318** have a smooth surface or a textured surface, the textured surface comprises grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof. The SI joint fixation system **300** may further comprise a fixation screw **302**, the fixation screw **302** comprises a head **320**, a shaft **322** and a thread **324**. The fixation screw **302** may further comprise a

collar. At least a portion of the fixation screw **302** contacts or mates to a portion of the bottom surface **314** of the base **308** and at least a portion of the first longitudinal member **310** and at least a portion of the second longitudinal member **312**. The spaced apart or the spacing between the first longitudinal member **310** and the second longitudinal member **312** is sized and configured to receive a portion of the fixation screw **302** and/or sized and configured to receive the shaft **322** of the fixation screw **302** to provide the “U-shape” wedging cage.

FIGS. 4A-4H depict various views of one embodiment of an O-shaped wedging cage system **400**. The wedging cage system **400** comprises a wedging cage **404** and a fixation screw **402**. The wedging cage **404** comprises a first base **408**, a second base **418**, a first longitudinal member **410** and a second longitudinal member **412**. The first base **408** including a threaded bore **406**, a top surface **416** and a bottom surface **414**, the threaded bore **406** extending from a top surface **416** through the bottom surface **414**. The second base **418** including a through-hole **428**, the through-hole **428** of the second base **418** is aligned with and/or concentrically aligned with the threaded bore **406** of the first base **408**. The first longitudinal member **410** and the second longitudinal member **412** spaced apart and extending between the first base **408** and the second base **418**. The first **410** and/or second longitudinal member **412** extending perpendicularly or substantially perpendicular from the first base **416** and/or the second base **418**, the substantially perpendicular includes 0.25 degrees to 10 degrees from neutral. The first **410** and/or second longitudinal member **412** including at least a portion of the at least one bone contacting surface **426** have a smooth surface or a textured surface, the textured surface comprises grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof. The SI joint fixation system **400** may further comprise a fixation screw **402**, the fixation screw comprises a head **420**, a shaft **422** and a thread **424**. The fixation screw **402** may further comprise a collar. At least a portion of the fixation screw **402** contacts or mates to a portion of the bottom surface **414** of the first base **408** and at least a portion of the first longitudinal member **410** and at least a portion of the second longitudinal member **412**. The spaced apart or the spacing between the first longitudinal member **410** and the second longitudinal member **412** is sized and configured to receive a portion of the fixation screw **402** and/or sized and configured to receive the shaft **422** of the fixation screw **402** to provide the “O-shape” wedging cage.

Alternatively, the O-shaped wedging cage system **400** may comprise a body. The body have a first end, a second end, and an aperture that is disposed between the first end and a second end. The aperture is sized and configured to receive the fixation screw **402** and/or the aperture is sized and configured to receive the shaft **422** of the fixation screw **402**. The aperture comprises an oval shape or circular shape. The first end of the body having a first bore and/or the second end of the body having a second bore. The first bore and the second bore concentrically aligned and/or axially aligned. The first bore and/or the second bore may comprise internal threads.

FIGS. 5A-5H depict various views of one embodiment of an L-shaped wedging cage **500**. The L-shaped wedging cage system comprises a wedging cage **500**. The wedging cage **500** comprises a base **502** and at least one longitudinal member **504**. The base **502** including a threaded bore **506**, at least one tool opening **508**, a top surface **510** and a bottom surface **512**, the threaded bore **506** extending from a top

surface **510** through the bottom surface **512**. The tool opening **508** is sized and configured to receive a portion of the insertion tool (not shown). The base **502** comprising a shape, the shape including an oval, square, rectangle, rounded square, rounded rectangle, and/or any combination thereof. The base **502** having a length **514**, a width **516** and a depth **522**. At least a portion of the base **502** having a smooth surface or a textured surface, the textured surface comprises grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof.

The at least one longitudinal member **510** extending from the base **502** and/or the bottom surface **512** of the base **502**. The at least one longitudinal member **504** extending perpendicularly (90 degrees) or substantially perpendicular from the base **502**, the substantially perpendicular includes 0.25 degrees to 10 degrees from neutral or a wedging cage axis **526**. The at least one longitudinal member **504** including at least one bone contacting surface **522**, a least a portion of the at least one bone contacting surface **522** having a smooth surface or a textured surface, the textured surface comprises grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof. The smooth or textured surface of the base **502** may be the same or different than the smooth or textured surface of the at least one longitudinal member **504**. At least a portion of the at least one longitudinal member **504** may be positioned adjacent to a circumference of the threaded bore **506** and/or the at least one longitudinal member may be positioned offset from the threaded bore **506** to provide for the “L-shape” wedging cage. The at least one longitudinal member may comprise a plurality of openings **520**, the plurality of openings being used to promote bone in growth and/or outgrowth. The plurality of openings **520** are spaced apart along a length **528** of the at least one longitudinal member **504**. The at least one longitudinal member **504** may comprise a tapered shape. The plurality of openings **520** may comprise different shapes, the shapes include a circle, an oval, a regular polygon or irregular polygon as shown in FIGS. 28B-28C). FIG. 28A illustrates a longitudinal member with the lack of openings or being solid.

FIGS. 6A-6H depict various views of one embodiment of a SI joint fixation system comprising a U-shaped wedging cage **600**. The U-shaped wedging cage **600** comprises a base **602**, a first longitudinal member **604** and a second longitudinal member **606**. The base **602** including a threaded bore **608**, at least one tool opening **612**, a top surface **610** and a bottom surface **620**, the threaded bore **608** extending from a top surface **610** through the bottom surface **620**. The first longitudinal member **604** and the second longitudinal member **606** spaced apart and extending from the bottom surface **620** of the base **602**. The first **604** and/or second **606** longitudinal member extending perpendicularly or substantially perpendicular from the base **602**, the substantially perpendicular includes 0.25 degrees to 10 degrees from neutral and/or the from neutral or a wedging cage axis **622**. The at least one tool opening **612** is sized and configured to receive a portion of an insertion tool (not shown). The base **602** comprising a shape, the shape including an oval, square, rectangle, rounded square, rounded rectangle, and/or any combination thereof. The base **602** having a length **614**, a width **616** and a depth **624**. At least a portion of the base **602** having a smooth surface or a textured surface, the textured surface comprises grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof.

The first **604** and/or second **606** longitudinal member including at least a portion of the at least one bone contacting surface **622** have a smooth surface or a textured surface, the textured surface comprises grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof. The first longitudinal member **604** and/or the second longitudinal member **606** may comprise a plurality of openings **620**, the plurality of openings being used to promote bone in growth and/or outgrowth. The plurality of openings **620** are spaced apart along a length **620** of the first longitudinal member **604** and/or the second longitudinal member **606**. The first longitudinal member **604** and/or the second longitudinal member **606** may comprise a tapered shape. The plurality of openings **620** may comprise different shapes, the shapes include a circle, an oval, a regular polygon or irregular polygon as shown in FIGS. **28B-28C**). FIG. **28A** illustrates at least one longitudinal member with the lack of openings or being solid.

The SI joint fixation system may further comprise a fixation screw (not shown) or axial screw (not shown), the fixation screw and/or the axial screw comprises a head, a shaft and a thread. The fixation screw may further comprise a collar. At least a portion of the fixation screw contacts or mates to a portion of the bottom surface **620** of the base **602** and at least a portion of the first longitudinal member **604** and at least a portion of the second longitudinal member **606**. Alternatively, the first longitudinal member **604** and the second longitudinal member **606** comprises a fixation screw contacting surface **618**. The spaced apart or the spacing between the first longitudinal member **604** and the second longitudinal member **606** is sized and configured to receive a portion of the fixation screw and/or sized and configured to receive the shaft of the fixation screw to provide the “U-shape” wedging cage. Accordingly, the SI joint fixation system may further comprise an axial screw. The axial screw is sized and configured to be inserted into the threaded bore **608**, the threaded bore **608** is sized and configured to receive at least a portion of the axial screw.

FIGS. **7A-7H** depict various views of one embodiment of a SI joint fixation system comprising an O-shaped wedging cage **700**. The wedging cage **700** comprises a first base **702**, a second base **726**, a first longitudinal member **704** and a second longitudinal member **706**. The first base **702** including a threaded bore **708**, at least one tool opening **712**, a top surface **710** and a bottom surface **728**, the threaded bore **708** extending from a top surface **710** through the bottom surface **728**. The second base **726** including a through-hole **720**, the through-hole **720** of the second base **726** is aligned with and/or concentrically aligned with the threaded bore **708** of the first base **702** and/or aligned with the wedging cage axis **722**. At least a portion of the base **702** having a smooth surface or a textured surface, the textured surface comprises grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof. The first base **702** and/or the second base **726** having a length **714**, a width **716** and a depth **724**.

The first longitudinal member **704** and the second longitudinal member **706** spaced apart and extending between the first base **702** and the second base **726**. The first **704** and/or second longitudinal member **706** extending perpendicularly or substantially perpendicular from the first base **702** and/or the second base **726**, the substantially perpendicular includes 0.25 degrees to 10 degrees from neutral and/or the wedging cage axis **722**. The first **704** and/or second longitudinal member **706** including at least a portion of the at

least one bone contacting surface **722** have a smooth surface or a textured surface, the textured surface comprises grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof. The first longitudinal member **704** and/or the second longitudinal member **706** may comprise a plurality of openings **720**, the plurality of openings **720** being used to promote bone in growth and/or outgrowth. The plurality of openings **720** are spaced apart along a length **720** of the first longitudinal member **704** and/or the second longitudinal member **706**. The first longitudinal member **704** and/or the second longitudinal member **706** may comprise a tapered shape. The plurality of openings **720** may comprise different shapes, the shapes include a circle, an oval, a regular polygon or irregular polygon as shown in FIGS. **28B-28C**). FIG. **28A** illustrates a longitudinal member with the lack of openings or being solid.

The SI joint fixation system may further comprise a fixation screw (not shown) or axial screw (not shown), the fixation screw and/or the axial screw comprises a head, a shaft and a thread. The fixation screw may further comprise a collar. At least a portion of the fixation screw contacts or mates to a portion of the bottom surface **728** of the first base **702** and at least a portion of the first longitudinal member **704** and at least a portion of the second longitudinal member **706**. Alternatively, the first longitudinal member **704** and the second longitudinal member **706** comprises a fixation screw contacting surface **718**. The spaced apart or the spacing between the first longitudinal member **704** and the second longitudinal member **706** is sized and configured to receive a portion of the fixation screw and/or sized and configured to receive the shaft of the fixation screw to provide the “O-shape” wedging cage. Accordingly, the SI joint fixation system may further comprise an axial screw. The axial screw is sized and configured to be inserted into the threaded bore **708**, the threaded bore **708** is sized and configured to receive at least a portion of the axial screw.

Alternatively, the O-shaped wedging cage **700** may comprise a body. The body have a first end, a second end, and an aperture that is disposed between the first end and a second end. The aperture is sized and configured to receive a portion of a fixation screw and/or the aperture is sized and configured to receive the shaft of the fixation screw. The aperture comprises an oval shape or circular shape. The first end of the body having a first bore and/or the second end of the body having a second bore. The first bore and the second bore concentrically aligned and/or axially aligned. The first bore and/or the second bore may comprise internal threads.

FIG. **8** depicts a side view of one embodiment of an SI joint fixation system comprising an I-shaped wedging cage **800**. The I-shaped wedging cage system comprises a wedging cage **800**. The wedging cage **800** comprises a base **802** and at least one longitudinal member **804**. The base **802** including a threaded bore (not shown), at least one tool opening (not shown), a top surface **806** and a bottom surface **808**, the threaded bore extending from a top surface **806** through the bottom surface **808**. The tool opening is sized and configured to receive a portion of the insertion tool (not shown). The base **802** comprising a shape, the shape including an oval, square, rectangle, rounded square, rounded rectangle, and/or any combination thereof. The base **802** having a length, a width and a depth. At least a portion of the base **802** having a smooth surface or a textured surface, the textured surface comprises grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof.

The at least one longitudinal member **804** extending from the base **802** and/or the bottom surface **80812** of the base **802**. The at least one longitudinal member **804** extending perpendicularly (90 degrees) or substantially perpendicular from the base **802**, the substantially perpendicular includes 0.25 degrees to 10 degrees from neutral or a wedging cage axis **810**. The at least one longitudinal member **804** including at least one bone contacting surface, a least a portion of the at least one bone contacting surface having a smooth surface or a textured surface, the textured surface comprises grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof. the smooth or textured surface of the base **802** may be the same or different than the smooth or textured surface of the at least one longitudinal member **804**. The at least one longitudinal member **804** may be positioned adjacent to a circumference of the threaded bore **506** and/or the at least one longitudinal member may be positioned offset from the threaded bore **506** to provide for the “L-shape” wedging cage. The at least one longitudinal member may comprise a plurality of openings (not shown), the plurality of openings being used to promote bone in growth and/or outgrowth. The plurality of openings are spaced apart along a length of the at least one longitudinal member **804**. The at least one longitudinal member **804** may comprise a tapered shape. The plurality of openings may comprise different shapes, the shapes include a circle, an oval, a regular polygon or irregular polygon as shown in FIGS. **28B-28C**). FIG. **28A** illustrates a longitudinal member with the lack of openings or being solid.

FIG. **9** depicts a side view of one embodiment of an SI joint fixation system comprising an H-shaped wedging cage **900**. The H-shaped wedging cage **900** comprises a base **902**, a first longitudinal member **904** and a second longitudinal member **906**. The base **902** including a threaded bore (not shown), at least one tool opening (now shown), a top surface **910** and a bottom surface **912**, the threaded bore extending from a top surface **910** through the bottom surface **912**. The first longitudinal member **904** and the second longitudinal member **906** spaced apart and extending from opposite sides of the base **902**. The first **904** and/or second **906** longitudinal member extending perpendicularly or substantially perpendicular from the base **902**, the substantially perpendicular includes 0.25 degrees to 10 degrees from neutral and/or the from neutral or a wedging cage axis **914**. The at least one tool opening is sized and configured to receive a portion of an insertion tool (not shown). The base **902** comprising a shape, the shape including an oval, square, rectangle, rounded square, rounded rectangle, and/or any combination thereof. The base **902** having a length **908**, a width and a depth. At least a portion of the base **902** having a smooth surface or a textured surface, the textured surface comprises grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof. The base **902** may extend between the first longitudinal member **904** and the second longitudinal member **906**, and be positioned anywhere along the length **908** of the first longitudinal member **904** and the second longitudinal member **906**.

The first **904** and/or second **906** longitudinal member including at least a portion of the at least one bone contacting surface **916** have a smooth surface or a textured surface, the textured surface comprises grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof. The first longitudinal member **904** and/or the second longitudinal member **906** may comprise a plurality of open-

ings (not shown), the plurality of openings being used to promote bone in growth and/or outgrowth. The plurality of openings are spaced apart along a length **908** of the first longitudinal member **904** and/or the second longitudinal member **906**. The first longitudinal member **904** and/or the second longitudinal member **906** may comprise a tapered shape. The plurality of openings may comprise different shapes, the shapes include a circle, an oval, a regular polygon or irregular polygon as shown in FIGS. **28B-28C**). FIG. **28A** illustrates a longitudinal member with the lack of openings or being solid.

The SI joint fixation system may further comprise a fixation screw (not shown) or axial screw (not shown). The fixation screw and/or the axial screw comprises a head, a shaft and a thread. The fixation screw may further comprise a collar. The fixation screw is intended to be positioned or deployed perpendicular to the axis **914** of the wedging cage. At least a portion of the fixation screw contacts or mates to a portion of the bottom surface **912** of the base **902** and at least a portion of the first longitudinal member **904** and at least a portion of the second longitudinal member **906**. Alternatively, the first longitudinal member **904** and the second longitudinal member **906** comprises a fixation screw contacting surface. The spaced apart or the spacing between the first longitudinal member **904** and the second longitudinal member **906** is sized and configured to receive a portion of the fixation screw and/or sized and configured to receive the shaft of the fixation screw to provide the “H-shape” wedging cage. Alternatively, the wedging cage **900** spaced apart or spacing between the first longitudinal member **904** and the second longitudinal member **906** is sized and configured to receive a portion of a two or more fixation screws. Each of the two or more fixation screws may be positioned adjacent to or contacting the top surface **910** of the base **902** and/or the bottom surface **912** of the base **902**. Accordingly, the SI joint fixation system may further comprise an axial screw. The axial screw is sized and configured to be inserted into the threaded bore, the threaded bore is sized and configured to receive at least a portion of the axial screw. The axial screw is intended to be positioned or deployed parallel to the axis **914** of the wedging cage **900**.

FIG. **10A-10C** depict various isometric views of different embodiments of surface textures disposed on wedging cages **1000**. Varying and/or enhancing the wedging cage surfaces may accelerate bone anchorage to the implants thereby providing optimal support for stability, osseointegration, and reduced complications. At least a portion of one bone contacting surface of the wedging cages **1000** described above may comprise a smooth surface and/or textured surfaces or modified surface. The textured surface comprises grit blasting, acid etching, laser texturing, plasma spraying, electropolishing, anodic oxidation, hydroxylapatite (HA), calcium phosphate (CaP), wave structures **1004**, pyramidal structures, reverse pyramidal structures **1006**, undulations, and/or any combination thereof. Alternatively, at least a portion of the one bone contacting surface of the wedging cages **1000** described above may comprise an osseointegration coating. The osseointegration coating comprises peptide coating, collagen coating, strontium titanate (SrTiO₃) coating, protein coatings, PEEK, and/or any combination thereof. The wedging cages **1000** may comprise an “H-shaped” wedging cage, “I-shaped” wedging cage, and “L-shaped” wedging cage, a “U-shaped” wedging cage and/or an “O-shaped” wedging cage.

FIGS. **11A-11E**, FIGS. **12A-12E** and FIGS. **13A-13E** depict various views of an alternative embodiment of fixation screws. The fixation screws comprise a head, shaft and

a thread. The fixation screws may comprise self-tapping screws. At least a portion of the screw length may have a fine or coarse self-tapping thread. The length of threaded portion of the screw is suitably from 10 to 50 mm. It is generally suitable to manufacture screws in various sizes such that the length of the said threaded portion varies so different sized screws can be chosen for any particular application. The head may comprise a channel, the channel may be disposed on the circumference of the head of the screw. The channel may be sized and configured to receive a portion of a collar. The head may further comprise a driving tool recess, the driving tool recess may comprise a shape that is sized and configured to receive a slotted driver, a cruciform driver, external polygon driver, internal polygon driver, hexalobular driver, three-pointed driver, special driver and/or any combination thereof. The screw shaft and thread may have a diameter. The shaft diameter may be smaller and/or greater than the thread. The fixation screws may further comprise a collar as shown in FIGS. 14A-14E. The collar may be self-leveling to at least one surface of the sacrum and/or ilium.

FIGS. 15A-15D depict isometric views of different embodiments on SI joint fixation system comprise a shell wedging cage 1500. The shell wedging cage 1500 comprises a wedging cage 1502 and a bone growth block 1504. The wedging cage 1500 comprises an "O-shaped" wedging cage. The "O-shaped" wedging cage comprises a body, the body including an aperture 1506. The aperture 1506 is sized and configured to receive the bone growth block 1504. The aperture may be frustum shaped allowing the bone growth block 1504 to be wedged into the aperture. The aperture 1506 may include different widths and lengths as shown in FIG. 15C-15D.

In another embodiment, the wedging cage 1502 may also comprise an "H-shaped" wedging cage, an "I-shaped" wedging cage, a "U-shaped" wedging cage, and an "L-shaped" wedging cage, and/or any combination thereof. At least a portion of the base, the at least one longitudinal member, the first longitudinal member, and/or the second longitudinal member may comprise a channel (not shown), the channel is sized and configured to receive a portion of the bone growth block 1504. Alternatively, at least a portion of the base, the at least one longitudinal member, the first longitudinal member, and/or the second longitudinal member may comprise a ledge (not shown), the ledge extends perpendicular from a surface of the base, the at least one longitudinal member, the first longitudinal member, and/or the second longitudinal member. The ledge having a top surface that contacts or mates with a portion of the bone growth block 1504.

FIGS. 16A-16G depict various views of one embodiment of an SI joint fixation system comprising an anchored wedging cage 1600. The anchored wedging cage comprises a wedging cage and an anchor assembly 1618. The wedging cage comprises a first base 1602, a second base 1626, a first longitudinal member 1604 and a second longitudinal member 1606. The first base 1602 including a bore 1608, at least one tool opening 1612, a top surface 1610 and a bottom surface, the bore 1608 extending from a top surface 1610 through the bottom surface 1628. The second base 1626 including a second bore or through-hole 1620, the through-hole 1620 of the second base 1626 is aligned with and/or concentrically aligned with the bore 1608 of the first base 1602 and/or aligned with the wedging cage axis 1622. The first base 1602 and/or the second base 1626 including a width 1616, a depth 1624, and a length 1624. At least a portion of the base 1602 having a smooth surface or a

textured surface, the textured surface comprises grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof. Alternatively, the wedging cage may comprise an I-shaped, L-shaped, H-shaped, O-shaped, U-shaped wedging cage and/or any combination thereof.

The first longitudinal member 1604 and the second longitudinal member 1606 spaced apart and extending between the first base 1602 and the second base 1626. The first 1604 and/or second longitudinal member 1606 extending perpendicularly or substantially perpendicular from the first base 1602 and/or the second base 1626, the substantially perpendicular includes 0.25 degrees to 10 degrees from neutral and/or the wedging cage axis 1622. The first 1604 and/or second longitudinal member 706 including at least a portion of the at least one bone contacting surface 1622 have a smooth surface or a textured surface, the textured surface comprises grit blasting, acid etching, laser texturing, wave structures, pyramidal structures, reverse pyramidal structures and/or any combination thereof. The first longitudinal member 1604 and/or the second longitudinal member 1606 may comprise a plurality of openings, the plurality of openings being used to promote bone in growth and/or outgrowth. The plurality of openings are spaced apart along a length 1620 of the first longitudinal member 1604 and/or the second longitudinal member 1606. The first longitudinal member 1604 and/or the second longitudinal member 1606 may comprise a tapered shape. The plurality of openings may comprise different shapes, the shapes include a circle, an oval, a regular polygon or irregular polygon as shown in FIGS. 28B-28C). FIG. 28A illustrates a longitudinal member with the lack of openings or being solid.

FIGS. 17A-17E depict various views of one embodiment of an anchor assembly 1700. The anchor assembly 1700 includes an anchor body 1702 and at least two pins 1704. The anchor body 1702 comprises a shaft 1706 and at least one flute 1708. The shaft 1706 further comprising a channel 1710 and a bore 1712. The channel 1710 being disposed around a circumference of the shaft 1706. The channel being sized and configured to receive a portion of the at least two pins 1704. The bore 1608 of the first base 1602 is sized and configured to receive a portion of the anchor assembly 1700. More specifically, the bore 1608 of the first base 1602 is sized and configured to receive the shaft 1706 the anchor assembly 1700. The bore 1712 may have a driving surfaces, the driving surfaces including a shape, the shape may be sized and configured to receive different drivers, the drivers may comprise slotted driver, a cruciform driver, external polygon driver, internal polygon driver, hexalobular driver, three-pointed driver, special driver and/or any combination thereof. The at least one flute 1708 being positioned around the circumference of the shaft 1706. In one embodiment, the anchor assembly 1700 comprises a first flute and a second flute, the first and second flute being positioned on the circumference of the shaft 1706 and on opposite sides symmetrically. The flutes cut a channel or remove bone during rotation, allowing the anchor assembly to be locked into place. The at least one flute 1708, the first flute and/or the second flute comprising a cutting surface 1714.

The anchor assembly is rotatable from an unlocked position to a locked position as shown in FIGS. 18A-18B. The unlocked position (see FIG. 18A) has the at least a portion of the anchor mating with a portion of the wedging cage and it allows the wedging cage to move or slide within the SI joint. The unlocked position has a low profile. The locked position (see FIG. 18B) rotates the anchor body anywhere between 1 degree to 90 degrees away from the portion of the

wedging cage and allows the wedging cage to lock into place within the SI joint by removing bone material within the SI joint to provide a positive stop. The positive stop reduces slippage, migration, and loosening.

FIGS. 19A-19D depict front views of various embodiments of the axial positioning of the anchor assembly within the anchored wedging cage system. The SI joint fixation system may have anchored wedging cages 1902, 1904, 1906, 1908 with different anchoring assembly lengths. The anchoring assemblies may be easily removable to allow the surgeon to have selectivity for different anchoring lengths. The anchoring assemblies comprise an anchor body, the anchor body comprises a shaft and at least one flute. The shaft including a length, the length may vary depending on the surgeons desired length and limited joint space.

FIGS. 20A-20C depict various views of one embodiment of an SI joint fixation system comprising an axial threaded wedging cage system 2000. The axial threaded wedging cage system 2000 comprises a wedging cage assembly 2002, and an insertion tool assembly 2004 the insertion tool assembly 2004 comprises a guiding cannula 2006 and an insertion cannula 2008 as shown in FIG. 20D. FIG. 20D depicts an exploded view of the axial threaded wedging cage system 2000 of FIGS. 20A-20C;

FIGS. 21A-2D depicts various views of one embodiment of a guiding cannula 2100. The guiding cannula 2100 comprising a handle 2102 and a shaft 2104. The handle 2102 includes a plurality of ribs 2106, the plurality of ribs 2106 are spaced apart and extend circumferentially from the handle 2102. The plurality of ribs 2106 are spaced apart symmetrically or non-symmetrically around the circumference of the handle 2102. The handle 2102 having a length 2118, the plurality of ribs 2106 extend at least portion of the length 2118. The handle 2106 further comprising a counter bore 2110 and internal threads 2112. The plurality of ribs 2106 comprising surface texture or surface roughness to prevent slippage and increase frictional handling. The handle 2102 has a circular or tubular shape.

The shaft 2104 comprising an elongated tube. The elongated tube having an outer diameter (OD), and inner diameter (ID) and a length 2116. The handle having a larger OD than the shaft OD. The guiding cannula 2100 comprising a bore 2114 that extends from a top end to a bottom end. The bore 2114 is sized and configured to receive a portion of the outer diameter of an insertion cannula 2200 (see FIGS. 22A-22E). The internal threads 2112 match or substantially match the external threads 2114 of the insertion cannula 2200.

The insertion cannula 2200 comprises a handle 2202 and a shaft 2204. The handle 2202 includes a plurality of ribs 2206, the plurality of ribs 2206 are spaced apart and extend circumferentially around the handle 2202. The plurality of ribs 2206 are spaced apart symmetrically or non-symmetrically around the circumference of the handle 2202. The handle 2202 having a length 2218, the plurality of ribs 2206 extend at least portion of the length 2218. The plurality of ribs 2206 comprising surface texture or surface roughness (not shown) to prevent slippage and increase frictional handling. The handle 2102 has a circular or tubular shape. The handle 2206 further comprising a first portion 2208 and a second portion 2210. The first portion 2208 outer diameter is greater than the second portion 2210 outer diameter. The first portion 2208 length is greater than the second portion 2210 length. The second portion 2210 is sized and configured to be disposed with the counter bore 2210 of the guiding cannula 2100.

The shaft 2204 comprising an elongated tube. The elongated tube having an outer diameter (OD), and inner diameter (ID) and a length 2118. The handle 2202 having a larger OD than the shaft OD. The insertion cannula 2200 comprising a bore 2222 that extends from a top end to a bottom end. The bore 2222 is sized and configured to receive a portion of the outer diameter of guiding wire (not shown). The handle 2202 having a first end and a second end. At least a portion of the first end comprising external threads 2212, the external threads 2212 is sized and configured to be disposed within the internal threads 2112 of the guiding cannula 2100. At least a portion of the second end comprising at least one elongated slot 2214. The at least one elongated slot 2214 may extend from the second end towards the first end and/or extend towards a portion of the length 220 of the shaft 2204. Alternatively, at least a portion of the second end comprising at least two elongated slots 2214, each of the at least two elongated slots are spaced apart and extend from the second end towards the first end, the spaced apart or spacing is symmetrical, non-symmetrical, and/or on opposite sides. At least a portion of the second end further comprising at least two grippers 2116, the at least two grippers are spaced apart and extend away from the second end or extend beyond a portion of the second end. The spaced apart or spacing is symmetrical, non-symmetrical and/or on opposite sides. The OD of the insertion cannula shaft 2204 is sized and configured to be disposed within the bore 2114 of the guiding cannula 2100.

FIGS. 23A-23D and 24A-24D depict one embodiment of a wedging cage assembly 2400. The wedging cage assembly 2400 comprises a wedging cage 2402 and an axial screw 2404. The wedging cage 2402 may comprise an "A-shaped" wedging cage, a "B-shaped" wedging cage, a "C-shaped" wedging cage, "H-shaped" wedging cage, an "I-shaped" wedging cage, an "O-shaped" wedging cage, an "L-shaped" wedging cage, a "U-shaped" wedging cage, a "M or W-shaped" wedging cage, and/or any combination thereof. In one particular embodiment, the wedging cage 2402 is an "O-shaped" wedging cage. The axial screw having a head, a shaft and threads.

In another embodiment, each of the wedging cages disclosed herein may comprise of different materials that are completely solid or porous. Porosity introduced into the materials allow enhanced bone in-growth and tissue differentiation. More specifically, the porosity elicits a stronger osteogenic response at the cellular response similar to textured or modified surfaces. Alternatively, at least a portion of the wedging cages may comprise of a solid material or a porous material. In addition, at least one surface of the wedging cages may comprise a solid material or a porous material. The porosity may include a plurality of connected, interstitial pores uniformly or non-uniformly distributed throughout the entire wedging cage, and/or at least a portion of the wedging cage. The average interstitial pore size comprises a range of 10 microns to 300 microns. The interstitial pores comprises a shape, the shape may match or substantially match trabecular or cortical pore shapes. Alternatively, the shape may comprise a circle, an oval, a polygon, and irregular polygon, and/or any combination thereof.

In another embodiment, each of the wedging cages disclosed herein may be manufactured from standard manufacturing techniques and/or 3D printing or additive manufacturing techniques. In another embodiment, at least a portion of the wedging cage and/or the entirety of a wedging cage may be manufactured from additive manufacturing methods (AM). Such AM methods include VAT photopoly-

merization, material jetting, binder jetting, material extrusion or fuse deposition modelling (FDM), power bed fusion (e.g., direct metal laser sintering (DMLS), electron beam melting (EBM), selective heat sintering (SHS), selective laser melting (SLM), selective laser melting (SLS), sheet lamination, and/or directed energy disposition (DED), multi-jet fusion, digital light synthesis, and/or any combination thereof.

VAT polymerization method uses a vat of liquid photopolymer resin, out of which at least a portion of the wedging cage can be constructed layer by layer. An ultraviolet (UV) light is used to cure or harden the resin where required, while a platform moves the structure being made downwards after each new layer is cured.

Material jetting approach can create a structure layer similar to using a two-dimensional ink jet printer. Material is jetted onto a build platform using either a continuous or Drop on Demand (DOD) approach. Material is jetted onto the build surface or platform, where it solidifies and the structure is built layer by layer. Material is deposited from a nozzle which moves horizontally across the build platform. The material layers are then cured or hardened using ultraviolet (UV) light.

The binder jetting approach uses two materials, a powder-based material and a binder. The binder acts as an adhesive between powder layers. The binder is usually in liquid form and the build material in powder form. A print head moves horizontally along the x and y axes of the machine and deposits alternating layers of the build material and the binding material. After each layer, the structure being printed is lowered on its build platform.

Fuse deposition modelling (FDM) is a common material extrusion process and is a technique used in domestic or hobby 3D printers. Material is drawn through a nozzle while under continuous pressure, where it is heated and is then deposited layer by layer into the desired cross-sectional area. The nozzle can move horizontally, and a platform moves up and down vertically after each new layer is deposited. Then the layers are fused together upon deposition as the material is in its melted state.

Powder bed fusion (PBF) methods use either a laser or electron beam to melt and fuse material powder together. All PBF processes involve the spreading of the powder material over previous layers into desired cross-sections. The powders are sintered, layer by layer. The platform lowers the structure to add additional layers, accordingly.

Directed Energy Deposition (DED) is a complex printing process commonly used to repair or add additional material to existing components. A typical DED machine consists of a nozzle mounted on a multi axis arm, which deposits melted material onto the specified surface and cross-section, where it solidifies. The process is similar in principle to material extrusion, but the nozzle can move in multiple directions and is not fixed to a specific axis. The material, which can be deposited from any angle due to 4 and 5 axis machines, is melted upon deposition with a laser or electron beam. The process can be used with polymers, ceramics but is typically used with metals, in the form of either powder or wire. Both conventional and additive manufacturing methods may be used together to create the desired structure pads, and/or any combination thereof.

FIGS. 27A-27I depict isometric views of different embodiments of an SI joint fixation system comprising a 3D printed wedging cage. The 3D printed wedging cage may comprise an A-shaped, a B-shaped, a C-shaped, H-shaped, I-shaped, L-shaped, O-shaped, U-shaped, a Y-shaped, and M or W shaped wedging cage and/or any combination thereof.

At least a portion of the 3D printed wedging cage comprises porosity 2402, 2404. The porosity 2402, 2404 may include a plurality of connected, interstitial pores uniformly or non-uniformly distributed throughout the entire wedging cage. The interstitial pores comprising a shape, the shape may match or substantially match trabecular or cortical patterns or shapes. Alternatively, the interstitial pores may have a shape, the shape may comprise a circle, an oval, a regular polygon or irregular polygon shape. The SI joint fixation system further comprises a screw (not shown), the screw is a fixation screw and/or an axial screw. The SI joint fixation system further comprises a delivery instrument (not shown), the delivery instrument includes a sleeve and an insertion cannula.

In another embodiment, the 3D printed wedging cage comprises a base 2706 and at least one longitudinal member 2708. At least a portion of the base 2706 comprises porosity 2402, 2404. The porosity 2402, 2404 may include a plurality of connected, interstitial pores uniformly or non-uniformly distributed throughout the entire wedging cage. The interstitial pores comprising a shape, the shape may match or substantially match trabecular or cortical patterns or shapes. Alternatively, the interstitial pores may have a shape, the shape may comprise a circle, an oval, a regular polygon or irregular polygon shape.

In another embodiment, the 3D printed wedging cage comprises a base 2706 and at least one longitudinal member 2708. At least a portion of the at least one longitudinal member 2708 comprises porosity 2402, 2404. The porosity 2402, 2404 may include a plurality of connected, interstitial pores uniformly or non-uniformly distributed throughout the entire wedging cage. The interstitial pores comprising a shape, the shape may match or substantially match trabecular or cortical patterns or shapes. Alternatively, the interstitial pores may have a shape, the shape may comprise a circle, an oval, a regular polygon or irregular polygon shape.

In another embodiment, the 3D printed wedging cage comprises a base 2706 and at least one longitudinal member 2708. At least a portion of the base 2706 and the at least one longitudinal member 2708 comprises porosity 2402, 2404. The porosity 2402, 2404 may include a plurality of connected, interstitial pores uniformly or non-uniformly distributed throughout the entire wedging cage. The interstitial pores comprising a shape, the shape may match or substantially match trabecular or cortical patterns or shapes. Alternatively, the interstitial pores may have a shape, the shape may comprise a circle, an oval, a regular polygon or irregular polygon shape.

In another embodiment, the 3D printed wedging cage comprises a base 2706 and at least one longitudinal member 2708. The entire base and/or the entire at least one longitudinal member 2708 comprises porosity 2402, 2404 as shown in FIG. 27I. The porosity 2402, 2404 may include a plurality of connected, interstitial pores uniformly or non-uniformly distributed throughout the entire wedging cage. The interstitial pores comprising a shape, the shape may match or substantially match trabecular or cortical patterns or shapes. Alternatively, the interstitial pores may have a shape, the shape may comprise a circle, an oval, a regular polygon or irregular polygon shape.

In another embodiment, the 3D printed wedging cage comprises a base 2706 and at least one longitudinal member 2708. The entire base and/or the entire at least one longitudinal member 2708 comprises a solid cross-section. Solid comprises a material that is not hollow.

FIGS. 29A-29F depict front views of the different embodiments of SI fixation system comprising different

shaped wedging cages. The wedging cages comprise an A-shaped wedging cage **2900**, a B-shaped wedging cage **2902**, a C-shaped wedging cage **2904**, and H-shaped wedging cage **2906**, an I-shaped wedging cage **2908**, L-shaped wedging cage **2910**, O-shaped wedging cage, U-shaped wedging cage, a Y-shaped wedging cage, and M or W shaped wedging cage. In one embodiment, the SI joint fixation system comprising a wedging cage **2900**, **2902**, **2904**, **2906**, **2908**, **2910** comprises a base **2920** and a first longitudinal member **2922**. The base having a bore, a top surface and a bottom surface. The first longitudinal member **2922** extending from a bottom surface of the first longitudinal member **2922**. The first longitudinal member **2922** may be positioned adjacent or proximate to the perimeter of the bore, and/or the first longitudinal member **2922** may be aligned or aligned concentrically with the bore.

The wedging cage **2900**, **2902**, **2904**, **2906**, **2908**, **2910** may further comprise a second longitudinal member **2924**. The first longitudinal member **2922** having a first end and a second end, and/or the second longitudinal member **2924** having a first end and a second end. The second longitudinal member **2924** may be positioned adjacent or proximate to the perimeter of the bore and/or on the opposite side of the bore. Alternatively, the second longitudinal member **2924** may be spaced apart from the first longitudinal member **2922**, and the first longitudinal member **2922** and the second longitudinal member **2924** extend from the bottom surface of the base **2920**. In addition, the first ends of the first longitudinal member **2922** and the second longitudinal member **2924** are coupled to the bottom surface of the base **2920**. The first longitudinal member **2922** having a length, the second longitudinal member **2924** having a length, the length of the first longitudinal member **2922** and the second longitudinal member **2924** being the same length or different lengths.

The wedging cage **2900**, **2902**, **2904**, **2906**, **2908**, **2910** may further comprise a lateral support member **2926**. The lateral support member **2926** may be positioned perpendicular or substantially perpendicular to the first longitudinal member **2922** and the second longitudinal member **2924**. The lateral support member **2926** may have a width, depth and length. The length may be equal to the spacing or the spaced apart dimension of the first longitudinal member **2922** and the second longitudinal member **2924**.

The wedging cage **2900**, **2902**, **2904**, **2906**, **2908**, **2910** may further comprise a second base **2928**. The second base **2928** is positioned at the opposite end of the first longitudinal member **2922** and/or the second longitudinal member **2924**. Alternatively, the second base **2928** is positioned at second end of the first longitudinal member **2922** and/or the second longitudinal member **2924**. The second base **2928** comprising a bore. The bore of the second base **2928** may align with an axis of the bore of the base **2920**.

In one embodiment the SI joint fixation system comprises combinations of different shaped wedging cages. For example, the SI joint fixation system comprises a first L-shaped wedging cage, a second L-shaped wedging cage and an I-shaped wedging cage. The I-shaped wedging cage is positioned between the first and second L-shaped wedging cage to produce an "M or W-shaped" wedging cage. The first and second L-shaped wedging cage are positioned spaced apart as mirror images of each other.

FIG. **29C** depicts a front view of one embodiment of an SI joint fixation system comprising a "C-shaped" wedging cage **2904** and a fixation screw (not shown).

Wedging Cage Materials

In various embodiments, the implants and/or portions may comprise silicon nitride and/or various combinations of a variety of surgically acceptable materials, including radiopaque and/or radiolucent materials, other materials or combinations of such materials. Radiolucent materials can include, but are not limited to, polymers, carbon composites, fiber-reinforced polymers, plastics, combinations thereof and the like. Radiopaque materials are traditionally used to construct devices for use in the medical device industry. Radiopaque materials can include, but are not limited to, metal, aluminum, stainless steel, titanium, titanium alloys, cobalt chrome alloys, combinations thereof and the like.

In another embodiment, each of the wedging cages disclosed herein may comprise different materials and/or combinations of materials. The materials may comprise metal, polymer, and/or ceramic. The metals comprise of titanium, steel, tantalum, cobalt-chrome, cobalt-chrome alloys, titanium alloy, nitinol and/or any combination thereof. Polymeric materials comprise PEEK. Ceramic materials comprise alumina, zirconia, silicon nitride, vitoss bone graft substitute, vitrium, and/or any combination thereof.

In another embodiment, the wedging cages disclosed herein can include a silicon nitride material (i.e., Si₃N₄ and/or chemical analogues thereof) in their construction, either in the entirety of the implant as well as components, portions, layers and/or surfaces thereof. The incorporation of silicon nitride as a component material for spinal or other implants can provide significant improvements over existing implant materials and material designs currently available, as the silicon nitride material(s) will be highly osteo-inductive and/or osteoconductive and will desirably facilitate and/or promote implant fixation to adjacent living bone surfaces, while concurrently reducing and/or inhibiting periprosthetic infection and/or bacterial adhesion to the surfaces and/or interior portions of the implant.

In various applications, the utility of silicon nitride as an implant material can be enhanced by the addition of various other medical materials, including the use of one or various combinations of titanium, chrome cobalt, stainless steel, silicone, poly (ether ether ketone) (PEEK), ultra-high molecular-weight polyethylene (UHMWPE), polyurethane foams, polylactic acid, apatites and/or various 3D printed materials. In such cases, the employment of such material mixtures in implant construction may enhance the strength and/or durability of a desired implant design, as well as allow for improved surgical outcomes and/or greatly reduced complication rates.

Silicon nitride (Si₃N₄) and its various analogs can impart both antibacterial and osteogenic properties to an implant, including to bulk Si₃N₄ as well as to implants coated with layers of Si₃N₄ of varying thicknesses. In bone replacement as well as prosthetic joint fusion and/or replacement, osseous fixation of implants through direct bone ingrowth (i.e., cementless fixation) is often preferred, and such is often attempted using various surface treatments and/or the incorporation of porous surface layers (i.e., porous Ti6Al4V alloy) on one or more bone-facing surfaces of an implant. Silicon nitride surfaces express reactive nitrogen species (RNS) that promote cell differentiation and osteogenesis, while resisting both gram-positive and gram-negative bacteria. This dual advantage of RNS in terms of promoting osteogenesis, while discouraging bacterial proliferation, can be of significant utility in a variety of implant designs.

Desirably, the inclusion of silicon nitride components into a given implant design will encompass the use of bulk silicon nitride implants, as well as implants incorporating other materials that may also include silicon nitride com-

ponents and/or layers therein, with the silicon nitride becoming an active agent of bone fusion. RNS such as N₂O, NO, and —OONO are highly effective biocidal agents, and the unique surface chemistries of Si₃N₄ facilitate its activity as an exogenous NO donor. Spontaneous RNS elution from Si₃N₄ discourages surface bacterial adhesion and activity, and unlike other direct eluting sources of exogenous NO, Si₃N₄ elutes mainly NH₄⁺ and a small fraction of NH₃ ions at physiological pH, because of surface hydrolysis and homolytic cleavage of the Si—N covalent bond. Ammonium NH₄⁺ can enter the cytoplasmic space of cells in controlled concentrations and through specific transporters, and is a nutrient used by cells to synthesize building-block proteins for enzymes and genetic compounds, thus sustaining cell differentiation and proliferation. Together with the leaching of orthosilicic acid and related compounds, NH₄⁺ promotes osteoblast synthesis of bone tissue and stimulates collagen type 1 synthesis in human osteoblasts. Conversely, highly volatile ammonia NH₃ can freely penetrate the external membrane and directly target the stability of DNA/RNA structures in bacterial cells. However, the release of unpaired electrons from the mitochondria in eukaryotic cells activates a cascade of consecutive reactions, which starts with NH₃ oxidation into hydroxylamine NH₂OH (ammonia monooxygenase) along with an additional reductant contribution leading to further oxidation into NO₂⁻ nitrite through a process of hydroxylamine oxidoreductase. This latter process involves nitric oxide NO formation. In Si₃N₄, the elution kinetics of such nitrogen species is slow but continuous, thus providing long-term efficacy against bacterial colonies including mutants (which, unlike eukaryotic cells, lack mitochondria). However, when slowly delivered, NO radicals have been shown to act in an efficient signaling pathway leading to enhanced differentiation and osteogenic activity of human osteoblasts. Desirably, Si₃N₄ materials can confer resistance against adhesion of both Gram-positive and Gram-negative bacteria, while stimulating osteoblasts to deposit more bone tissue, and of higher quality.

Where the presence of bulk silicon nitride implant materials may not be desired and/or may be impractical for some reason, it may be desirable to incorporate modules and/or layers (such as surface and/or subsurface layers) including silicon nitride on other materials. Silicon nitride structures and/or components can be formed using a variety of techniques, including by compressing, milling and firing silicon nitride powder, as well as by extruding silicon nitride into sheet, tube, pipe and/or thread form (which may be further processed into thread or “rope” by braiding and/or other techniques). Silicon nitride shapes may also be manufactured using subtractive manufacturing techniques (i.e., machining, milling and/or surface roughening), as well as by using additive manufacturing techniques (i.e., surface coating, brazing, welding, bonding, deposition on various material surfaces and/or even by 3D laser printing of structures). If desired, silicon nitride may even be formed using curing or other light/energy activation techniques, such as where a slurry of liquid polymer and silicon nitride particles may be UV cured to create a 3-dimensional structure and/or layer containing silicon nitride. In various embodiments, silicon nitride may be utilized in block form, in sheets, columns and bars, in cable or braided form, in mesh form, in a textured surface coating, in powder form, in granular form, in gel, in putty, in foams and/or as a surface filler and/or coating. In some cases, a surface layer of silicon nitride may be formed on an external and/or internal surface of an implant.

For example, in some embodiments it may be desirable to laser-sinter a thin layer of silicon nitride material (i.e.,

powder) to the surface of another material, such as PEEK or titanium. One exemplary starting micrometric powder used for laser-sintering of a Si₃N₄ coating in this manner could comprise a 90 wt % fraction of Si₃N₄ powder mixed with a 6 wt % of yttrium oxide (Y₂O₃) and a 4 wt % of aluminum oxide (Al₂O₃). If desired, a Vision LWI VERGO-Workstation equipped with a Nd:YAG laser with a wavelength of 1064 nm (max pulse energy: 70 J, peak power 17 kW, voltage range 160-500 V, pulse time 1-20 ms, spot size 250-2000 μm) can be utilized to achieve densification of successive layers of Si₃N₄ powder placed on a water-wet surface of a Titanium substrate in a nitrogen environment, which desirably limits Si₃N₄ decomposition and oxidation. In the exemplary embodiment, the Nd:YAG laser can be pulsed with a spot size of 2 mm, and driven by an applied voltage of 400 V with a pulse time of 4 ms. This operation can be repeated until a continuous thickness of 15 μm (±5 μm) is formed over an entire surface of the Titanium substrate. This process can create a wavy morphology of the ceramic/metal interface, with interlocks at the micrometer scale between metal and ceramic phases and desirably little or no diffusional transport of the Titanium element into the coating during laser sintering.

In other exemplary embodiments, silicon nitride materials of differing compositions and/or states (i.e., solid, liquid and/or flowable or moldable “slurry” states, for example) could be utilized in a single implant and/or portions thereof, including the use of solid silicon nitride for a base or cage for an implant or wedge, and/or the employment of a moldable silicon nitride “paste” placed within a centrally positioned “graft chamber” of a titanium or PEEK implant.

In various embodiments, the materials may comprise properties that would desirably include improvements or enhancements to the wedging cages disclosed herein, these include one or more of the following: (1) Flexibility in manufacturing and structural diversity, (2) Strong, tough and reliable constructs, (3) Phase stable materials, (4) Favorable imaging characteristics through radiopaqueness, (5) Hydrophilic surfaces and/or structures, (6) Osteoconductive, (7) Osteoinductive, and/or (8) Anti-Bacterial characteristics and/or bacteriostatic.

SI Wedging Cage Methods

The SI joint fixation system is adaptable to variety uses for treatment of SI joint dysfunction via fixation and fusion techniques. The SI joint fixation system may comprise a wedging cage and axial screw, a wedging cage and fixation screw, and a wedging cage (provided alone to be used in conjunction with standard fusion or fixation instrumentation). The SI joint fixation system may be used with open surgical techniques and/or minimally invasive techniques. The minimally invasive techniques comprise an anterior and/or posterior approach.

In one embodiment, the SI joint fixation system may be adapted to be deployed before the fixation screws are implanted as shown in FIGS. 25A-25C. The method comprises the steps of placing the patient under general anesthesia, cutting a small incision over the lower back and muscles are gently moved to the side, drilling a small hole through the ilium to access the joint, clearing the sacroiliac joint of ligaments and muscles; deploying the SI joint fixation system into the SI joint; deploying the fixation screws through the SI joint and the SI joint fixation system to encourage bone growth; repositioning muscles into place, and closing the surgical site using standard sutures.

The SI joint fixation system may be adapted to be deployed after the fixation screws are implanted as shown in FIGS. 26A-26C. The method comprises the steps of placing

the patient under general anesthesia, cutting a small incision over the lower back and muscles are gently moved to the side, drilling a small hole through the ilium to access the joint, clearing the sacroiliac joint of ligaments and muscles; deploying the fixation screws through the SI joint, deploying the SI joint fixation system onto the fixation screws to encourage bone growth; repositioning muscles into place, and closing the surgical site using standard sutures.

While embodiments and applications of the present subject matter have been shown and described, it would be apparent that other embodiments, applications and aspects are possible and are thus contemplated and are within the scope of this application.

All references, including publications, patent applications, and patents, cited herein are hereby incorporated by reference to the same extent as if each reference were individually and specifically indicated to be incorporated by reference and were set forth in its entirety herein.

The various headings and titles used herein are for the convenience of the reader and should not be construed to limit or constrain any of the features or disclosures thereunder to a specific embodiment or embodiments. It should be understood that various exemplary embodiments could incorporate numerous combinations of the various advantages and/or features described, all manner of combinations of which are contemplated and expressly incorporated hereunder.

The use of the terms “a” and “an” and “the” and similar referents in the context of describing the invention are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The terms “comprising,” “having,” “including,” and “containing” are to be construed as open-ended terms (i.e., meaning “including, but not limited to,”) unless otherwise noted. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., i.e., “such as”) provided herein, is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

Preferred embodiments of this invention are described herein, including the best mode known to the inventor for carrying out the invention. Variations of those preferred embodiments may become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventor expects skilled artisans to employ such variations as appropriate, and the inventor intends for the invention to be practiced otherwise than as specifically described herein. Accordingly, this invention includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the invention unless otherwise indicated herein or otherwise clearly contradicted by context

We claim:

1. An SI joint fusion system comprising:

a wedging cage, the wedging cage comprising a first base, a first longitudinal member and a second longitudinal member, the first base including a top surface, a bottom surface and a threaded bore, the first longitudinal member including a first proximal end and a first distal end, the first distal end of the first longitudinal member extending away from a portion of the bottom surface of the first base, the second longitudinal member including a second proximal end and a second distal end, the second distal end of the second longitudinal member extending away from a portion of the bottom surface of the first base, the first distal end of the first longitudinal member being spaced apart from the second distal end of the second longitudinal member with an opening formed therebetween at the first and second distal ends, the threaded bore extending from the top surface of the base through the bottom surface of the base; and a screw, the screw comprising a head, a shank portion and a threaded portion, the opening between the first and second distal ends being sized to allow the screw to pass between the first and second distal ends.

2. The SI joint fusion system of claim 1, wherein the first longitudinal member is positioned adjacent to a perimeter of the threaded bore.

3. The SI joint fusion system of claim 1, wherein the first longitudinal member and the second longitudinal member are spaced apart along their entire lengths.

4. The SI joint fusion system of claim 3, wherein the wedging cage comprises a second base, the second base being positioned proximate to a midpoint of the first longitudinal member and the second longitudinal member.

5. The SI joint fusion system of claim 3, wherein the first longitudinal member and the second longitudinal member comprise different lengths.

6. The SI joint fusion system of claim 1, wherein the first base further comprises a first channel and a second channel, the first and second channel positioned on opposite sides of the base.

7. The SI joint fusion system of claim 1, wherein the first longitudinal member comprises at least one bone contacting surface, at least a portion of the at least one bone contacting surface including a smooth or textured surface.

8. The SI joint fusion system of claim 3, wherein the first longitudinal member and the second longitudinal member each comprise at least one bone contacting surface, at least a portion of the at least one bone contacting surface of each member including a smooth or textured surface.

9. The SI joint fusion system of claim 3, wherein the first longitudinal member comprises a first plurality of apertures and the second longitudinal member comprises a second plurality of apertures.

10. An SI joint fusion system comprising:

a first base and a first longitudinal member, the first base including a top surface, a bottom surface, and a threaded bore, the first longitudinal member extending away from a first portion of the bottom surface of the first base to a first distal end, the bottom surface of the first base and an inner surface of the first longitudinal member partially enclosing a central space, the central space having an open front surface and an open back surface, each positioned substantially transverse to an implant plane extending through a height dimension of the system, wherein the system comprises an implant plane extending through the first base and the first longitudinal member, the central space having an open peripheral edge substantially aligned with the implant

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plane extending through the first base and the first longitudinal member, the threaded bore extending from the top surface of the base through the bottom surface of the, base.

11. The SI joint fusion system of claim 10, further comprising a second longitudinal member extending along the implant plane extending through the first base and the first longitudinal member, the second longitudinal member extending away from a portion of the bottom surface of the first base, the first longitudinal member and the second longitudinal member being spaced apart.

12. The SI joint fusion system of claim 11, further comprising a second base.

13. The SI joint fusion system of claim 10, wherein the first base further comprises a first channel and a second channel, the first and second channel positioned on opposite sides of the base.

14. The SI joint fusion system of claim 11, wherein the first longitudinal member and the second longitudinal member each comprise at least one bone contacting surface, at

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least a portion of each of the at least one bone contacting surfaces including a smooth or textured surface.

15. The SI joint fusion system of claim 10, wherein the first longitudinal member comprises a plurality of apertures.

16. The SI joint fusion system of claim 10, wherein the SI joint fusion system further comprises a screw, the screw comprising a head, a shank portion and a threaded portion, the screw being inserted into the threaded bore.

17. The SI joint fusion system of claim 16, wherein the screw comprises a fixation screw or axial screw.

18. The SI joint fusion system of claim 10, further comprising an anchor, the anchor being rotatable between a retracted position and a deployed position.

19. The SI joint fusion system of claim 18, wherein the anchor comprises a shaft, a first blade and a second blade, the first and second blade extend outwardly from the shaft and are spaced apart.

20. The SI joint fusion system of claim 10, wherein the first longitudinal member is positioned adjacent to a perimeter of the threaded bore.

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